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A COMPENDIOUS and METHODICAL ACCOUNT OF THE PRINCIPLES OF Natural Philoſophy:

As they are Explain'd and Illuſtrated in the
Courſe of EXPERIMENTS, perform'd
at the ACADEMY in Little *Tower-Street.*

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THE
PREFACE.

THE Deſign of the following Sheets is not to deſcribe the *Apparatus*, or the Manner of performing the Experiments, which may be underſtood much eaſier and better by ſeeing the Inſtruments and Experiments themſelves, than by all the Books that have been publiſh'd in that Way; but only to ſhew how the ſolid Principles of true Philoſophy are deduced from the *Phænomena* of Nature, and what Dependence of particular Cauſes upon general Laws may be rationally concluded from a ſufficient Number of certain and undoubted Obſervations.

NOR is it intended to treat this Matter in a Pompous and Declamatory Way, whereby Truths and Falſhoods are equally capable of being render'd plauſible, and propagated with Succeſs, and which ought therefore to be rejected and deſpiſed by every Man who deſires to diſtinguiſh Truth from Falſhood: But here nothing more is meant, than to propoſe Things in the ſhorteſt and plaineſt Method, and to make uſe of ſuch Reaſonings and Arguments as are not applicable to any falſe Notion, or mere Hypotheſis, how ingeniouſly ſoever contrived.

THE great Objection againſt all Enquiries into Nature is, that they are dangerous, and many times prejudicial to Religion.

I take Notice of this Objection the rather, becauſe it is induſtriouſly propagated by many Perſons who ought to know better; and indeed I am inclined to think, that the chief Deſign of keeping up this Clamour, is to put a good Face upon their own Ignorance. However, it is no new thing for Men to deſpiſe and vilify what they don't underſtand, whatever be the Reaſon of it.

My Lord *Bacon* obſerved a great while ago, (*Cogitata & viſa*, p. 11.) "That the moſt troubleſome and ill-"natur'd Enemy that Natural Philo-"ſophy had, was Superſtition, or a "blind intemperate Zeal for Reli-"gion. ---- The weakeſt of theſe "Objectors (ſays he) are afraid, "leſt, by enquiring too deeply into "Nature, we ſhould exceed thoſe "Bounds of Modeſty and Sobriety "which GOD has ſet us; hereby miſ-

“applying to the *Secrets of Nature*, what is only true of *Divine Myſteries*, many of which are indeed ſhut up from Humane Underſtandings under a Divine Seal. Others more craftily conjecture, that ſo long as Men are utterly ignorant of Natural Cauſes, it will be much eaſier to make them believe that all Things are wrought by the immediate Hand of God, and a miraculous Direction of Providence. Thus they think to make a Compliment to the Supreme Being by Falſhood and Lyes. Others are afraid of making an ill Precedent; and they don't know but Alterations in Philoſophy may introduce Alterations in Religion. And laſtly, others ſeem very ſolicitous, leſt by Natural Inquiſitions ſomething ſhould be found out at laſt which ſhould overthrow Religion. But theſe two laſt Apprehenſions ſavour very

“ much of Infidelity and Carnal Wiſ-
“ dom; and as to the latter, it is
“ impious to ſuppoſe, or even ſuſpect
“ it. It is certain therefore, that un-
“ der theſe Objections, there lies con-
“ cealed much Weakneſs, much En-
“ vy, and much Malice.” Thus far my Lord *Bacon*.

And indeed, as to thoſe Perſons whoſe chief Merit and Trade it is to *lye for God, and to accept the Perſon of the Moſt High*, and all for the Sake of their own Intereſt and Paſſions: As to ſuch Perſons, I ſay, their *Integrity* and *Abilities* begin to be ſo well known in the World, that I believe no good Man will much regard either their Praiſe or Diſpraiſe.

I conclude therefore, that the Modern Diſcoveries of the Beauty and Regularity of the Creation, which have been made by a cloſe and diligent Attention to the Works of Nature, tend more to the Advancement of God's Glory, and the Diſplaying his Perfections to Mankind, than the fineſt Periods and moſt elaborate Harangues of the greateſt Orator can do.

Dec. 30. 1721.

THE

THE CONTENTS.

OF Natural Philoſophy in general. p. 1.
Of the Properties of all Bodies. p. 3.
Of Space. p. 5.
Of Attraction and Repulſion. p. 9.
Of the Attraction of Gravitation. p. 11.
Of the Attraction of Coheſion. p. 17.
Of Repulſion. p. 23.

MECHANICS.

OF the Nature of Reſt and Motion. p. 30.
Of Machines in general. p. 32.
Of the Simple Machines. p. 36.

The Contents.

LAWS of MOTION.

The First Law of Motion. p. 43.
Of the Motions, Diſtances, and Periods of the Planets. p. 46.
The Second Law of Motion. p. 52.
Of the Deſcent of Heavy Bodies in a direct Line. p. 53.
Of the Motion of Projectiles. p. 56.
Of Reſiſting Mediums. p. 58.
Of the Motion of the Moon and Tides. p. 60.
Of Oblique Deſcents and Pendulums. p. 69.
The Third Law of Motion p. 80.
Of Elaſticity. p. 82.
Of the Communication of Motion. p. 88.

HYDROSTATICS.

Of the Gravitation and Preſſure of Fluids in general, but more particularly of Incompreſſible Fluids. p. 99.
Of Siphons and Pumps. p. 107.
Of Spouting Water. p. 109
Of Running Water. p. 118
Of the Gravitation of Solids and Fluids together. p. 123.

PNEUMATICS.

OF the Gravitation and Preſſure of Elaſtic or Compreſſible Fluids. p. 132.
Of Air and its Elaſticity. p. 135.
Of Damps and Peſtilence. p. 139.
Of Heat, Vapours, and Flame. p. 144.
Of Pneumatic Engines. p. 159.

OPTICS.

OF the Rays of Light. p. 163.
Of Refraction. p. 165.
Of the Refraction of Rays by a Plane Surface. p. 173.
Of the Refraction of Rays by a Plane Surface. p. 175.
Of the Refraction of Rays by a Spherical Surface. p. 179.
Of a Lens. p. 181.
Of the Refraction of Rays by a Convex Glaſs. p. 182.
Of the Refraction of Rays paſſing through a Concave Glaſs, p. 190.
Of the Meniſcus, p. 191.
Of the Eye. ibid.

Of

Of Combinations of Glaſſes. p. 195.
Of the Reflection of Rays. p. 202.
Of Mirrours. p. 210.
Of Colours. p. 215.
Of the Permanent Colours of Natural Bodies. p. 222.
Of Colours in the Clouds, and of the Rainbow. p. 225.

A COMPENDIOUS and METHODICAL ACCOUNT OF THE PRINCIPLES OF Natural Philoſophy.

Of NATURAL PHILOSOPHY in general.

ANY Report of our Senſes concerning external or corporeal Objects is called a Phænomenon.

If a Phænomenon be agreeable to the ſtated and ordinary Courſe of Things, it is called a *Natural* Phænomenon.

The Buſineſs of Natural Philoſophy is to deduce from Experiments ſuch Laws as the ordinary and ſtated Courſe of Nature is govern'd by, and to referr the natural Phænomena to thoſe Laws.

In doing this, we are to obſerve the following Rules, as they are laid down by Sir *Iſaac Newton*, *Princip. Lib.* 4.

1. No other Cauſes of natural Things ought to be admitted, but ſuch as are true in Fact, and ſufficient to explain the Phænomena. This is agreeable to thoſe receiv'd Maxims, that Nature does nothing in vain; and that it is in vain to make uſe of more things, where fewer will do as well: For Nature always takes the beſt and wiſeſt Courſe, that is, the moſt ſimple and free from Superfluity.

2. Wherefore the Cauſes of all natural Effects of the ſame kind, are the ſame; as the Cauſe of Reſpiration in Man and other Animals; of the Deſcent of a Stone in *Europe* and in *America*; of Light in common Fire and in the Sun; of the Reflexion of Light in the Earth and in the Planets.

3. Such Properties of Bodies as are incapable of Augmentation and Diminution, and ſuch as belong to all Bodies in which we can make Experiments, are to be eſteem'd univerſal Properties of Bodies.

Of the PROPERTIES *of all Bodies.*

THE firſt is, that they are all induced with Magnitude, and extended in Length, Breadth and Thickneſs; for where there is no Magnitude, there can be no Contact.

2. All Bodies are hard or impenetrable; for if they were not, they could not reſiſt the Touch, or affect our Senſes; even the ſofteſt Bodies will be found to be as hard as any, if we keep their Parts from ſlipping away.

3. All Matter is capable of being divided into Parts, that is, into Halves, Quarters, Tenths, Hundredth Parts, *&c.* For that which has no Parts, can have no Magnitude or Extenſion, and therefore cannot be Matter. By being divided into Parts, we do not here mean the *actual Separation* of thoſe Parts from each other, but only the conceiving in the Mind ſuch Parts as are *really diſtinct* from each other.

4. All Matter is capable of being divided for ever; otherwiſe we ſhall neceſſarily come at laſt to ſuch Matter as cannot be divided at all, which is contrary to the third Property.

That there can be no end to the Diviſibility of Matter, is both certain and eaſy to be conceiv'd. The only Reaſon why ſome Perſons have thought the Notion *myſterious* and inexplicable, was, becauſe they did not know how to diſtinguiſh between a Particle of a certain determinate Bigneſs, and a true and real Part in a Mathematical Senſe; that is, as it ſtands in relation to its Whole, and receives its Denomination (as Half, Quarter, *&c.*) by being compared with that greater Magnitude, of which the leſſer is a Part.

By the infinite Diviſibility of Matter, is not meant that there are contained an infinite Number of Particles of a determinative Bigneſs in any finite Quantity of Matter, how great ſoever. This is abſolutely impoſſible.

But the only Meaning is, that no Part of Matter can be conceived ſo ſmall, but we may conceive a ſmaller; to which purpoſe nothing elſe is neceſſary, but to double or treble, *&c.* the Denominator of the Fraction by which the Part is expreſſed.

It is not therefore at all difficult to conceive how a very ſmall Particle of Matter has as many Parts as a very large Body. On the contrary, it would be ſtrange if it ſhould be otherwiſe; for how can a Mountain have more Halves, Quarters, or Tenths, than a Mole-hill?

5. All Bodies may change their Situation by moving from one Place to another, or

continue in the ſame Situation by remaining at Reſt in their own Places.

6. All Matter is ſluggiſh and inactive, and unable to move itſelf: And therefore if one Body contains a greater Quantity of Matter than another, it ſhall alſo have more Inactivity; that is, it ſhall require a greater Force to make it move with the ſame Degree of Swiftneſs with which the other is made to move.

Wherefore if two Bodies move with an equal Swiftneſs, and meet with no Reſiſtance, either the Quantities of Matter in the moving Bodies are equal, and the Forces by which the Motions are produced equal; or elſe the Quantities of Matter are unequal, and the Forces unequal alſo in the ſame Proportion; for an equal Inactivity will be overcome by an equal Force, and a greater Inactivity requires a greater Force to overcome it.

Of SPACE.

IF we conceive any one Body to be removed or annihilated, whilſt all other Bodies remain at Reſt in their proper Places; that Place which the firſt Body fill'd, ſhall then be void of all Matter, and capable of receiving again into itſelf either the ſame Body that was taken out of it, or any other Body of the ſame Size and Shape.

Place void of all Matter is called *Space* or *Vacuum*; concerning which there have been three Opinions:

1. That there was no ſuch thing *in* the Univerſe, whatever there might be *without* it.

2. That there was no ſuch thing in being, and that the very Notion of it implied a Contradiction.

3. That tho' perhaps in Nature there were no large Tracts or Regions of empty Space, yet that it had a great Share in the Texture and Compoſition of all Bodies that are known to us.

Now that the Notion of Space is not inconſiſtent, is evident from the Idea that has been already given of it.

That Space exiſts diſtinct from Matter, and that it may be ſeparated from all Matter, may be thus proved.

It is certain from Experiment, that if Bodies deſcend in the Air, thoſe that are very light ſhall be ſenſibly retarded by the Reſiſtance of the Air; but in the exhauſted Receiver of the Air-Pump, all Bodies, howſoever differing in Weight, Shape or Magnitude, ſhall fall with an equal Swiftneſs.

It is plain therefore, that by exhauſting the Receiver, the Reſiſtance of the Air is in Fact either removed, or at leaſt ſo much diminiſhed, as to be render'd inſenſible.

Now the Reſiſtance made by any Medium to a Body moving in it, ariſes either from that Force which is neceſſary to ſeparate the Parts of the Medium, if they are in any Degree ſticking and tenacious; or from that Force which is neceſſary to overcome the *Inertia* or Inactivity of all that Part of the Medium which lies in the way of moving Body.

But with regard to the Air, the firſt kind of Reſiſtance is very inconſiderable; and in all Caſes, the ſecond kind of Reſiſtance is proportional to the Quantity of Matter in the reſiſting Medium, as is evident from the ſixth Property of Bodies.

Hence it follows clearly, that becauſe there is leſs Reſiſtance in the exhauſted Receiver, therefore there is leſs Matter, and therefore there is more Vacuity than there was before exhauſting.

Of all Bodies, (except of the heavieſt of all) it may be proved from their different Specifick Gravities, that they have many Vacuities or Pores void of all Matter interſpers'd between their ſolid Parts.

When one Body weighs more than another of the ſame Bigneſs, or as much as another that is bigger, then the firſt is ſaid to be *ſpecifically heavier* than the ſecond.

Let us ſuppoſe, for Example, a Bullet of Lead, and a Ball of Cork, both of an equal Bigneſs.

Now it has been already ſhewn, that in a *Vacuum*, or where there is no Reſiſtance, if the Lead and the Cork begin to fall at the ſame time, they will move equally faſt.

Therefore the Quantity of Matter in the Bullet is to the Quantity of Matter in the Ball, as the Force that moves the Bullet is to the Force that moves the Ball; that is, as the Weight of the Bullet to the Weight of the Ball: Therefore the Bullet has more Matter than the Ball, and the Ball more *Vacuum* than the Bullet.

If Gold be the heavieſt of all Bodies, as it is of all known Bodies, then we may affirm of all Bodies in general, that they contain Vacuities amongſt their ſolid Parts: For the Particles of Heat and Magnetiſm find an eaſy Paſſage thro' the Pores of Gold, and even Water itſelf has been forced thro' them.

If we conſider how freely the Rays of Light paſs thro' ſo ſolid a Body as Glaſs in all manner of Directions, we ſhall find Reaſon to believe, that Bodies are much more porous than is commonly imagin'd; ſo that perhaps in the heavieſt of them the Quantity of Space may be ſeveral times greater than the Quantity of Matter.

Of ATTRACTION *and* REPULSION.

BESIDES the inactive Principles of Matter and Space, there are found in Nature certain active Powers, or Principles of Motion, whereby Bodies are carried towards or from each other, according to certain fix'd and determinate Laws, which may be call'd the Laws of Attraction and Repulſion.

Attraction and Repulſion are not here conſider'd as the Occult Qualities of Bodies, but only as the General Laws of Nature, eſtabliſh'd from the Beginning by the Author of Nature; in Conſequence of which, Bodies in ſuch or ſuch Circumſtances are made to tend towards, or fly from each other with ſuch or ſuch Velocities.

Attraction and Repulſion are not *Occult* Qualities; for the Qualities themſelves, that is, the Tendencies of Bodies towards or from each other, according to certain Laws, are manifeſt, plain, and certain, from a Multitude of Phænomena and Experiments.

Nor is the *Cauſe* of theſe active Principles altogether occult and unknown; for tho' perhaps it may be difficult to determine how far ſome of theſe Principles may depend upon any of the reſt, or whether all of them do not flow from ſome other more general

Principle, as yet undiſcover'd; yet this is moſt evident and certain, that either theſe active Principles themſelves, or at leaſt that more general one from whence they reſult, is altogether immechanical and independent from Matter, and can only proceed from the firſt Cauſe and Author of all things.

It is true indeed, that theſe Laws are but general Concluſions, preſumed to be true from an Induction of many Particulars; and it cannot be proved demonſtrably, but that there may be Exceptions to theſe Laws in ſome other Particulars, which have never yet been tried or obſerved.

But then we muſt obſerve on the other hand,

1. That the Induction upon which theſe general Concluſions are founded, is very large and extenſive.

2. That we have no reaſon to expect any thing in Nature, but what is *regular and uniform*; for the Creation was not the Effect of Chance, but of conſummate Wiſdom and Contrivance, whereby all things were eſtabliſh'd according to the niceſt Rules of Number, Weight, and Meaſure, that is, of Mathematicks.

3. That when theſe active Principles are call'd General Concluſions, it is only meant that they ſhould be pronounced General, till Exceptions are found out; and if at any time

afterwards, any Exception ſhall occurr from the Phænomena or Experiments, they ſhould thence-forward begin to be pronounced with ſuch Exception.

4. That tho' arguing by Induction is not an abſolute Demonſtration; yet in Natural Philoſophy, it is the beſt way of arguing that the Nature of Things admits of; for by this Method more of Nature may be known, and has actually been diſcover'd, than can be known, or has been diſcover'd by any other Method whatſoever.

5. That nothing can be more reaſonable than to argue from Effects to Cauſes, and from the Exiſtence of ſuch or ſuch Motions to the Forces producing them.

Of the ATTRACTION *of* GRAVITATION.

IT is certain from the Phænomena of Nature, and will be explain'd more particularly hereafter, that as all heavy Bodies near the Earth tend to its Center, with a Force proportional to their Quantity of Matter; ſo the Moon alſo tends to the Center of the Earth according to the ſame Law, and the Waters of the Sea tend to the Center of the Moon; and both Earth and Moon, and all the Planets and Comets, tend towards the Sun, and towards each other.

Therefore we conclude from the third Philoſophical Rule, that all Bodies within the Solar Syſtem tend towards, or attract each other, with Forces proportional to the Quantity of Matter that each Body contains.

All Bodies attract more or leſs in Proportion to the Quantity of Matter they contain: Thus the Attraction of the Sun is ſtronger, and the Attraction of the Moon weaker, than that of the Earth.

For the Attraction of each particular Body, is nothing elſe but the Sum of the Attractions of all its Parts.

But the Effect of that Attraction in Spheres that are homogeneal, at equal Diſtances from the Center, is the ſame as if the whole attracting Force were united in the Center of the Sphere, as is evident from the Deſcent of heavy Bodies in right Lines from all Parts towards the Center of the Earth.

All Vertues or Qualities which are propagated in right Lines from a Center, decreaſe in the ſame Proportion as the Squares of the Diſtances from the Center increaſe; as is eaſily proved both from the Nature of the thing and from Experiments.

And becauſe Gravitation is ſuch a Vertue or Quality as was juſt now deſcribed, therefore it muſt alſo decreaſe according to the ſame Rule.

This is all that is meant when it is ſaid, that at different Diſtances from the ſame attracting Body, *the Forces of Attraction are reciprocally as the Squares of the Diſtances.*

At all equal Diſtances from the ſame Center of Attraction, the Force is proportional to the Quantity of Matter in the Body attracted, as has been already proved: Therefore in all Caſes, the Attraction is as the Quantity of Matter directly, and the Square of the Diſtance reciprocally.

Here it muſt be obſerv'd, that if two Quantities increaſe or decreaſe in the ſame Proportion that two other Quantities increaſe or decreaſe; then the two former are ſaid to be *directly as* the two latter, or in *direct Proportion of* the two latter.

Thus the Quantities of Matter in Bodies are directly as the Weight of thoſe Bodies; that is, as the Weight of one Body is to the Weight of another, ſo is the Quantity of Matter in the firſt, to the Quantity of Matter in the ſecond.

But if two Quantities increaſe in the ſame Proportion that two other Quantities decreaſe, or if the two former decreaſe in the ſame Proportion that the two latter increaſe, then the two former are ſaid to be *reciprocally as* the two latter, or in *reciprocal Proportion of* the two latter.

Thus the Weight of Bread is reciprocally proportional to the Price of Corn; that is, as the Price of Corn at one time is to the Price of Corn at another time, ſo is the Weight of Bread at the ſecond time to the Weight of Bread at the firſt.

If two Quantities are proportional to the Squares of two other Quantities, the two former are ſaid to be in *Duplicate Proportion* of the two latter. Thus 8 to 18 is in Duplicate Proportion of 2 to 3. For as 4 is to 9, ſo is 8 to 18.

If two Quantities are proportional to the ſquare Roots of two other Quantities, the two former are ſaid to be in *Subduplicate Proportion* of the two latter. Thus 8 to 18 is in Subduplicate Proportion of 16 to 81: For as 8 to 18, ſo is 4 to 9.

Subduplicate Proportion is nearer to a Proportion of Equality, than a ſimple Proportion; and a Simple Proportion is nearer to a Proportion of Equality, than Duplicate Proportion.

If two Quantities are as the Product of two Numbers to the Product of two Numbers, then thoſe Quantities are ſaid to be in Compound Proportion of thoſe Numbers. Thus 6 to 20 is in Compound Proportion of 4 to 8, and 6 to 10. For as 6 is to 20, ſo is 4 times 6 to 8 times 10.

But to return to the Attraction of Gravitation, let A, B be two attracting Bodies, and C, D two attracted Bodies.

1. Now if A, B are equal, and C, D are equal, and the Diſtance of C from A equal to the Diſtances of D from B; then the Gravitations of C and D ſhall be equal.

2. But if the Quantity of Matter in A be double to the Quantity of Matter in B, all other Circumſtances continuing as they were; then the Gravity of C ſhall be double to the Gravity of D.

3. Again, if the Diſtance of C from A is to the Diſtance of D from B, as 2 to 3, every thing elſe remaining according to the firſt Suppoſition; then the Gravity of D ſhall be to the Gravity of C, as 4 to 9.

4. If A is double to B, and C quadruple to D, and the Diſtances equal; then the Gravity of C ſhall be eight times greater than that of D.

5. If the Quantities of Matter are as in the ſecond Caſe, and the Diſtances as in the third; then the Gravities of C and D ſhall ſhall be as 8 to 9.

6. If the Quantities of Matter be as in the fourth Caſe, and the Diſtances as in the third; then the Gravities ſhall be as the Product of the Numbers 2, 4 and 9, to the Product of the Numbers 1, 1 and 4; that is, as 72 to 4, or 18 to 1.

That Increaſe of the attracting Force which ariſes from the Quantity of Matter in the attracting Body, is call'd the *Abſolute Force:*

That Increaſe of the attracting Force which ariſes from the Smalneſs of the Diſtance, is call'd the *Accelerating Force.*

But the entire Force of Gravity, ariſing from both the former Conſiderations, together with the Quantity of Matter in the Body attracted, is call'd the *Moving Force.*

At the Surfaces of two homogeneal Spheres of different Diameters, the Attractions of two equal and homogeneal Bodies ſhall be as the Diameters of the Spheres.

For the abſolute Forces ſhall be as the Cubes of the Diameters, and the accelerating Forces ſhall be reciprocally as the Spheres of the Semidiameters or Diameters; therefore the moving Forces ſhall be as the Semidiameters or Diameters.

Within the Surface of the Earth, (ſuppoſing it in all Parts equally denſe) or any other attracting ſolid homogeneal Sphere, the accelerating Force decreaſes, as the Diſtance from the Center decreaſes.

For at the Center there is no Attraction at all; and at any Diſtance between the Center and the Surface, the Attraction of the whole Sphere is diminiſh'd by the contrary Attraction of its upper Part: For it is eaſily proved by Geometry, that if a Particle of

Matter were placed any where within a concave Sphere compos'd of attractive Particles, the Particle within would not be at all affected by the Attractions of the Particles which compoſe the concave Sphere: Wherefore the Attractions of the Earth below the Surface at different Diſtances from the Center, are the ſame that the Attractions of ſuch ſolid Spheres would be, whoſe Semidiameters were equal to thoſe Diſtances; that is, the Attractions ſhall be as the Semidiameters or Diſtances.

Hence it follows, that the Attraction is ſtrongeſt of all at the Surface of the Earth; for below the Surface, it decreaſes with the Diſtance; and above the Surface, it decreaſes as the Squares of the Diſtances increaſe.

Of the ATTRACTION *of* COHESION.

IT is evident from a Multitude of Experiments, that the Parts of Matter attract each other with a Force different from that of Gravity, and of a different kind. The Properties of this new Attraction are theſe:

1. The Force is by much the ſtrongeſt when the Parts touch each other.

2. The ſmaller the Diſtance, the ſtronger the Attraction; and if the Diſtance be very ſmall, the Force is very conſiderable.

3. At greater Diſtances, this ſort of Attraction is inſenſible.

4. Wherefore it decreaſes much more than as the Squares of the Diſtances increaſe; elſe it would be perceivable at great Diſtances, as the Attraction of Gravitation is.

5. Perhaps it may decreaſe nearly in reciprocal Proportion of the Cubes of the Diſtances, and at ſome determinate ſmall Diſtance entirely ſtop.

6. In Particles of an equal Size, the abſolute Force of Attraction is ſtrongeſt in that which contains the greateſt Quantity of Matter; for all Vacuity is void of Attraction.

7. Among Particles of an equal Size and Denſity touching each other, the Attraction is ſtrongeſt where the Surface of Contact is largeſt.

8. The Attraction is ſtronger between ſmall Particles than large, if the Particles are equally denſe, and the Surface of Contact equal: For the Effect of the ſame Force has a greater Proportion to the Weight and *Inertia* of a ſmall Quantity, than of a large Quantity.

The Ebullitions, Fermentations, and Cryſtallizations of the Chymiſts, are the plain Effects of ſuch an Attraction.

That the Drops of Fluids endeavour to form themſelves into a round Figue, is owing to the mutual Attractions of their Parts:

And that they are ſometimes hinder'd from forming themſelves into that Shape, is owing to the Attraction of ſome neighbouring Body, whoſe Vertue is ſtronger than that of the Parts of the Fluid.

Another manifeſt Proof of this Attraction is the Aſcent of Water in ſmall open Glaſs Tubes above the Level of the Water into which the End of the Tube is dipt. Here it is evident, that the Water tends towards, or is attracted by the Glaſs, and endeavours to unite itſelf to it.

The Circumſtances of this Experiment are worth remarking, which are theſe:

1. In every particular Tube, the Water riſes to a certain Height, and then ſtops.

2. And in all Tubes, the utmoſt Height to which the Water riſes, is reciprocally proportional to the Diameter of the Bore of the Tube, without any regard to the Thickneſs of the Glaſs, or the Length of the Tube.

3. Wherefore in all Tubes, the Quantity of the Water is directly proportional to the Diameter of the Tube: For we know from Geometry, that the Quantity of Water contain'd in Tubes of equal Heights and different Diameters, is directly proportional to the Squares of the Diameters. Wherefore if the Height be reciprocally as the Diameters,

meters, the Quantity contain'd ſhall be as the Diameters directly.

4. At the greateſt Height, the Weight of the Water raiſed is equal to the Attraction of the Tube that raiſes it.

5. The Attraction which raiſes and ſupports the Water, proceeds only from that Ring of Particles which lie in the Concave Surface of the Tube next above the Surface of the Water in the Tube: For if it proceeded from other Particles within the ſolid Glaſs, the utmoſt Height of the Water would depend in part at leaſt upon the Thickneſs of the Glaſs, and not entirely upon the Diameter of the Bow. If the Attraction proceeded from the empty upper Part of the Tube, then the different Lengths of that upper Part would produce different Effects: Nor can it proceed from the Attraction of thoſe Particles beyond which the Water has aſcended; for theſe Particles attract downwards as much as upwards, and therefore can contribute nothing either to the raiſing or ſupporting the Water. Wherefore the whole Weight of the Water that is raiſed, hangs by the uppermoſt Ring of the Particles to which it is contiguous.

6. Hence it is evident, that the Quantity of Water at the greateſt Height in every Tube ought to be proportional to the Diameter of the Tube, as always in Fact it is;

for the Quantity of Water ought to be proportional to the Force of Attraction, and the Force of Attraction is as the Number of attracting homogeneal Particles, and the Number of the attractive Particles muſt be proportional to the Bigneſs of the Circle which thoſe Particles compoſe: And it is certain from Geometry, that the Bigneſs of the Circle is proportional to the Length of its Diameter, that is, of the Diameter of the Tube.

7. Hence alſo it is proved, that this kind of Attraction acts only at ſmall Diſtances; for the whole Quantity of Water is ſuſtain'd by ſuch Particles as are almoſt contiguous to it.

The Pores of a Spunge in ſucking up Water are in the Nature of ſmall Tubes, and act by the ſame Power.

There is another Experiment upon this Head that deſerves a particular Explanation, and that is the Motion of a Drop of Oil between two poliſh'd Glaſs Plates, touching each other at one End, ſo as to contain a very ſmall Angle between them. Here it is evident,

1. That the Drop moves towards the Concourſe of the Glaſſes, becauſe the Attractions of both the Surfaces incline that way.

2. That the Attraction becomes ſtronger, as the Drop approaches nearer to the Line of Contact. This appears becauſe the Plates of Glaſs muſt be more inclin'd to the Horizon before the Attraction can be overcome, and the Drop made to deſcend.

3. That if there be ſeveral Drops at an equal Diſtance from the Line of Concourſe, the largeſt moves faſteſt, becauſe the largeſt Drops being the flatteſt, their Surface of Contact with the Glaſſes is not only greater than that of the ſmall Drops, but alſo greater in Proportion to the Quantity of Oil. Wherefore many times a large Drop ſhall overtake a ſmall one, which at firſt had got the Start of it by a conſiderable Diſtance.

4. That the Attractions of the ſame Drop at different Diſtances from the Line of Concourſe, are nearly in a reciprocal Proportion of the Squares of the Diſtances of the Center of the Drop from the Concourſe of the Glaſſes: For by the ſeventh and eighth Laws of this ſort of Attraction, the Force is in Proportion compounded of the Thinneſs of the Drop, and the Largeneſs of its Surface of Contact; both which are in a reciprocal Proportion of the Diſtance from the Line of Concourſe.

Having proved the Reality of this Attraction, it is no difficult Matter to ſhew farther, that ſuch a Power is ſufficient to explain how the Parts of Bodies may ſtick together with as many different Degrees of Coheſion as have been obſerved in Nature.

Therefore by the firſt Philoſophical Rule, this Attraction ought to be eſteem'd the true Cauſe of the Coheſion of Parts, and for that Reaſon it is call'd the *Attraction of Coheſion.*

Particles of Matter whoſe Weight is greater than their Attraction, can produce only an incoherent Maſs like a Heap of Sand.

Particles of Matter whoſe Attraction is but very little greater than their Weight, ſhall conſtitute a Fluid.

Particles of Matter whoſe Attraction is very much greater than their Weight, ſhall form a compact and ſolid Body.

If the Attraction exceeds the Weight of the Particles in a moderate Degree, they will compoſe a ſoft Body.

Of REPULSION.

WHERE the Force of Attraction ends, a new Force, which is that of Repulſion, begins.

1. If the Diſtance of two Particles be ſo great that the Sphere of Attraction cannot reach from one to the other, they ſhall fly from or repel each other with a Force that increaſes, as the Diſtance of the Particles decreaſes.

2. When

2. When a Particle that is repell'd, is forced within the Sphere of Attraction, it ſhall be attracted; and when a Particle that is held by Attraction, is thrown off by ſome ſuperior Force beyond the Sphere of Attraction, it ſhall be repell'd.

3. Thoſe Particles which are attracted moſt ſtrongly when within the Sphere, ſhall be repell'd moſt forcibly when without it.

4. The repelling Force between a hard Body and a ſoft, is generally leſs than between two hard Bodies, and greater than between two ſoft Bodies.

5. The Parts of a ſolid Body may be ſo diſpos'd as to attract the Parts of a Fluid with great Violence, tho' the Attraction between a ſingle Part of the Solid and a ſingle Part of the Fluid may be very weak, and conſequently the repulſive Force between the fluid and ſolid Body but ſmall.

It is from ſuch a repulſive Force that we find it difficult to mix Oil and Water, that is, to make their Parts touch and attract each other ſo as to ſtick together.

The Repulſion between Glaſs and Water is eaſily overcome, that is, it is eaſy to wet the Glaſs with Water, or make the Water ſtick to the Glaſs; but it is not eaſy to overcome the Repulſion between Glaſs and crude Quickſilver, or to apply the Quickſilver to the Glaſs with ſo much Force as is requiſite to bring it within the Sphere of Attraction.

The repelling Force between Quickſilver and poliſh'd Steel, is ſtronger than between Quickſilver and Copper; and between Quickſilver and Copper, ſtronger than between Quickſilver and Gold.

From this Principle of Repulſion it is, that a ſmall Needle, if dry, ſwims upon the Water; and that Flies walk upon it without wetting their Feet.

Salt is ſpecifically heavier than Water; yet a ſmall Quantity of Salt being diſſolv'd in a large Quantity of Water, will not ſink to the Bottom, but diffuſe itſelf equally thro' the whole Maſs. Wherefore as ſoon as the Parts of the Salt are ſeparated by the Attraction of the Water, they recede from each other as much as poſſible, (that is, they repel each other, till they all ſtand at equal Diſtances) and communicate an equal Degree of Saltneſs to all Parts of the Water.

Some Bodies are reduced by Fire into Vapour and Smoak, others are only melted: The Reaſon is, becauſe Heat is able to ſeparate the Parts of ſome Bodies with ſuch a Force, as to drive them beyond the Reach of each others Attraction; but in other Bodies, the Particles are of a fit Size, and have a ſufficient Attraction to make them endure the Agitations of Heat, without being entirely ſeparated.

If one Glaſs Priſm be laid upon another, the Rays of Light ſhall be copiouſly reflected in all oblique Angles from all Parts of the lower Surface of the uppermoſt Priſm: But if the Priſms are preſs'd hard together, there will appear in that Surface a dark tranſparent Spot; the Light, which was before reflected, being now attracted into the undermoſt Priſm, upon its near Approach, and tranſmitted thro' it. Hence it clearly follows, that the Priſms did not touch each other before they were compreſs'd; and that therefore they were kept aſunder by a repelling Force, *greater than the Weight of the incumbent Priſm.*

Hence it is, that if a Fluid be divided, it eaſily unites again, the repelling Force being but ſmall; but if a Piece of Glaſs be broke, and the Parts laid together in the ſame Order they were in at firſt, with never ſo much Exactneſs, yet the Repulſion is too ſtrong to admitt of a Reunion.

Thus alſo, if hard Subſtances are pounded to dry Powders, the divided Parts will not eaſily ſtick together, unleſs they are firſt wetted with ſome Fluid, (as Oil or Water) whoſe repelling Force is very weak, and afterwards brought together again, by gradually exhaling the intervening Fluid with a gentle Heat.

That the Parts of Water are ſo eaſily ſeparated by Heat, and rarified into Vapour, is an Argument of the Smalneſs of their attracting Force; that being once ſeparated, they are ſo eaſily condens'd by Cold, and turn'd into Water again, is an Argument of the Smalneſs of their repelling Force.

The fifth Property of this Law of Repulſion is very obſervable in the Diſſolution of Metals in their proper *Menſtruums*; for *Aqua Fortis* meets the Filings of Iron without Difficulty, and is afterwards attracted by the Iron with ſo much Violence, as to looſen and divide the Parts of the Metal with a great Heat and Ebullition.

When the Particles of Metals, or the like hard and denſe Subſtances, are emitted or thrown off by a violent Heat or Fermentation, there will be produced a Fluid, (like that of Air) the Parts of which will recede from each other as far as poſſible, and repel with leſs Force the farther they recede.

Such Fluids as theſe are call'd *Elaſtick* Fluids, becauſe they are capable of Condenſation or Dilatation, as the Force that preſſes them is greater or leſſer than the repelling Force.

Heat and Cold paſs thro' the denſeſt Bodies, and are alſo conveyed thro' the artificial *Vacuum* to all Parts of the exhauſted Receiver. Hence it appears, that the Air floats in a Medium much more ſubtile than itſelf, which ſubtile Medium is elaſtick, and remains ſuſpended in the Receiver even after the Air is exhauſted.

This ſubtile elaſtick Medium (which may be call'd *Æther*) is expanded thro' the whole Solar Syſtem, and conveys the Heat of the Sun with an immenſe Swiftneſs to the moſt diſtant Parts.

The Rays of Light, when their Motion is deſtroy'd, ſeem to conſtitute this Æther, or at leaſt to mix with it.

If we conceive the Attraction of Gravitation towards the Body of the Sun, or any fix'd Star, to be confin'd within the Limits of the reſpective Syſtems of the Sun or Star, and that without thoſe Limits a repelling or centrifugal Force begins; this centrifugal Force will be ſufficient to keep the Sun and fix'd Stars in their proper Places, and hinder them from falling upon one another, and will be a kind of Wall or Partition about every particular Syſtem, and ſeems not to be unſuitable to the Regularity and Uniformity of the Works of Nature.

Electrical Attraction and Repulſion ſeem to be in moſt of their Properties of a like Nature with the Principles that have been now explain'd.

Wherefore perhaps Electrical Attraction is nothing elſe but the Attraction of Coheſion, excited by a ſtrong Attrition to act with leſs Force in a larger Sphere.

It is evident from ſeveral Experiments, that in Electrical Attraction, the Particles of Light and Æther are forcibly repell'd or driven away from the Electrical Body; and that this Force reaches to a conſiderable Diſtance, but is ſtrongeſt near the Electrical Body.

Hence it follows, that the Æther is denſer, and its Elaſticity ſtronger, at greater Diſtances from the Electrical Body. Wherefore Leaf-Gold, or any other attracted Body, ſhall be driven from thoſe Parts where the Preſſure is greateſt, towards thoſe Parts where the Preſſure is leaſt, that is, toward the Electrical Body.

When the Leaf-Gold is forcibly emitted by ſtrong and ſmart Vibrations of the Electrical Body beyond the Sphere of Attraction, the Gold itſelf ſeems to become electrical, and to vibrate and repel the Æther, till the Vertue or Motion of its Parts is deſtroy'd by the Contact of ſome other Body. Now two Bodies ſurrounded each with an electrical Sphere of its own, ought to repel each other, becauſe the Æther is repell'd by both, and condens'd between 'em, and the Spheres thereby hinder'd from breaking in upon one another.

MECHA-

MECHANICKS.

MEchanicks is that Part of Natural Philoſophy, which treats of the Nature and Laws of Motion.

Of the Nature of REST *and* MOTION.

THE Continuance of a Body in the ſame Place, for any Space of Time, is call'd *Reſt*.

A continual Change of Place or leaving one Place and acquiring another, without remaining for any Space of Time in the ſame Place, is call'd *Motion*.

The Place of a Body is that Space which it fills.

A Body is ſaid to be in the ſame Place abſolutely, when it does not paſs from one Part of immovable Space to another.

A Body is ſaid to be in the ſame Place relatively, when its Place keeps the ſame Situation with reſpect to other Bodies.

Wherefore Reſt and Motion are of two Kinds, Abſolute and Relative.

A Body may be abſolutely at Reſt, and relatively in Motion; as a Bullet, if it were made to move juſt as faſt as the Earth moves, but the contrary way.

So alſo a Body may be relatively at Reſt, and abſolutely in Motion; as all things that are fix'd to the Earth, and carried along with it.

A Line drawn from the moving Body that way that the Motion tends, is call'd the Line of Direction.

That Property of Motion by which the moving Body deſcribes a certain Space in a certain Time, is call'd the Swiftneſs or Velocity of the Motion.

So long as the Velocity continues the ſame, the Motion is called *Uniform*; when the Velocity becomes greater than it was before, the Motion is ſaid to be *accelerated*; and when the Velocity grows leſs, the Motion is ſaid to be *retarded*.

1. In two Bodies moving uniformly, the Velocities are as the Spaces deſcrib'd in equal Times, or reciprocally as the Times in which equal Spaces are deſcrib'd, or always in compound Proportion of the Spaces directly, and Times reciprocally; and the Spaces deſcrib'd are always in compound Proportion of the Times and Velocities.

2. If two unequal Bodies move uniformly with equal Velocities, the Quantity of Motion in each Body is proportional to its reſpective Quantity of Matter, as is evident from the bare Conſideration of the *Inertia* of Matter.

3. If two equal Bodies move uniformly with unequal Velocities, the Quantities of Motion are as the Velocities: For a double Velocity cannot be impreſs'd upon an equal Quantity of Matter, without a double moving Force; and therefore the Effect, that is, the Motion produc'd, muſt be double.

4. Wherefore, if two unequal Bodies move uniformly with unequal Velocities, the Quantity of Motion is in compound Proportion of the Quantities of Matter, and the Velocities of the moving Bodies. This is alſo confirm'd to be true by Experiment.

The Quantity of Motion in any moving Body, is call'd its *Momentum*.

Of MACHINES *in general.*

1. ANY thing by the Help of which a Body is either moved or hindred from moving, is call'd a *Machine*.

2. The Body which is moved or hindred from moving, is call'd the *Weight*. That which moves or ſuſtains the Weight, is call'd the *Power*.

3. By the Motion of the Weight, we are not to underſtand the Motion of its Center of Gravity in a Horizontal Line, nor the Circular Motion of its Parts about the Center of Gravity; for in both theſe Caſes the Gravitation of the Body is no Impediment

to its Motion: But by the Motion of the Weight, is only meant the Aſcent or Deſcent of its Center of Gravity; the Motion of the Center of Gravity farther from, or nearer towards the Center of the Earth.

4. We muſt diſtinguiſh three Centers: The Center of Magnitude of a Body, which is a Point taken as much as poſſible equally diſtant from all the outward Parts.

The Center of Motion of a Body, which is any Point upon which the Body may reſt, or about which it may move.

The Center of Gravity of a Body, which is a Point about which all the Parts of the Body balance each other; ſo that if that Point be made the Center of Motion, the Body may be placed and will continue at Reſt in any Situation whatſoever.

5. Sometimes theſe three Centers fall upon one Point, ſometimes upon two, and ſometimes upon three different Points.

6. The Property of the Center of Gravity is always to deſcend whenſoever it is at Liberty to deſcend, that is, whenſoever it is not ſtopped by any thing, or ſuſpended upon any thing that lies in a direct Line paſſing thro' the Center of the Earth and the Center of Gravity.

7. A Body cannot ſtand, or retain its Poſition, either upon a Horizontal or inclined Plane, unleſs a Perpendicular, let fall from

the

the Center of Gravity, falls within the Baſe.

8. In all Bodies that are ſuſpended, the Center of Gravity is either directly over or directly under the Center of Motion.

9. That Point of a Machine about which the Weight and Power move, or upon which they ſuſtain each other, is called the fix'd Point.

10. The Diſtance from the fix'd Point to that Part of the Machine where the Weight or Power is applied, is called the *Diſtance* of the Weight or Power.

11. The *Angle of Application* is the Angle made by the Machine, and the Line of Direction of the Weight or Power.

12. The Quantity of a Power is eſtimated by ſome determinate Force of Gravity equivalent thereto. Thus a Power of ten Pounds, is a Power whoſe Force is equal to the Weight of ten Pounds.

13. It is the ſame thing whether a Machine be employ'd to lift ſome Weight, or to overcome ſome Reſiſtance or Force equivalent to that Weight.

14. When the Quantities of Motion in the Weight and Power are equal, the Machine ſhall ſtand in *Æquilibrio*; but when they are unequal, the greater Quantity of Motion ſhall overcome and work the Machine.

15. Of Forces in themſelves equal, that which is neareſt to the fix'd Point, is relatively the weakeſt upon the Machine; for as the Machine works, the neareſt Force moves the ſloweſt, and therefore has the leaſt Quantity of Motion.

16. The Effect of any Force upon a Machine will not be changed, if without changing the Line of Direction, we only place it in ſome other Point of the ſame Line.

17. Hence it follows, that if the Angle of Application be oblique, and a Perpendicular be let fall from the fix'd Point to the Line of Direction, the Force ſhall be no greater upon the Machine, than if it were applied at Right Angles at the End of the Perpendicular.

18. In treating of Machines, we are to conſider them as mathematically exact and perfect, and moving without Friction.

19. The Nature of any Machine is explained, when it is known in what Circumſtances the Weight and Power will be in *Æquilibrio* upon that Machine.

20. In any Machine whatſoever, the Weight and the Power will be in *Æquilibrio*, when their Quantities are in reciprocal Proportion of the Velocities, which the Working of the Machine would give them; for they will be in *Æquilibrio*, when the Quantity of Motion is equal on each ſide. Now

the Quantities of Motion are in compound Proportion of the Velocities and Quantities of Force. Therefore when the Quantities of Force are reciprocally as the Velocities, the Quantities of Motion ſhall be equal.

Of the SIMPLE MACHINES.

A Balance is nothing but a right Line moving freely upon a fix'd Point. The *Æquilibrium* will happen at all times, when the Quantities of the Power and Weight are reciprocally as their Diſtances.

One Weight may be in *Æquilibrio* with one equal or unequal Weight, or with ſeveral equal or unequal Weights; and ſeveral equal or unequal Weights may be in *Æquilibrio* with an equal or unequal Number of other Weights. For if the Sum of the Products of each Weight, multiplied into its reſpective Diſtance on one ſide the Balance, be equal to the Sum of the like Products on the other ſide, the Quantities of Motion ſhall be equal on each ſide.

Thoſe Weights which are in *Æquilibrio* upon a Horizontal Balance, will remain in *Æquilibrio* when the Balance is inclined, provided the Lines of Direction continue parallel to each other.

When an inclined Balance returns to a Horizontal Situation, the Reaſon is becauſe the common Center of Gravity of the Balance and Weights falls below the fix'd Point.

The *Statera Romana*, or Steel-Yard, is a Balance with unequal Arms; the common Scales is a Balance with equal Arms.

Falſe Scales are diſcovered by changing the Weights from each Scale to the other.

If by falſe Scales, the Seller will gain one Ounce in ſixteen; then by changing the Weights, the Buyer ſhall gain one Ounce and $\frac{1}{15}$ of an Ounce over.

A Leaver differs from a Balance only in the Manner of uſing it. Leavers are of four Kinds:

1. When the fix'd Point is between the Weight and the Power.

2. When the Weight is between the fix'd Point and the Power.

3. When the Power is between the fix'd Point and the Weight.

4. When the Diſtance of the Weight makes an Angle at the fix'd Point with the Diſtance of the Power.

In all the four Kinds there will be an *Æquilibrium*, when the Forces are in reciprocal Proportion of their Diſtances.

A compound Leaver is eaſily explained upon the ſame Principles.

If a Power is to ſupport two Weights hanging at the End of a Leaver, the Power muſt be equal to the Sum of the Weights, and placed between them, ſo that the Diſtances ſhall be reciprocally as the Weights: For in this Caſe the Power is in the Place of a fix'd Point.

If the Weights at the End of the Leaver be conſidered as Powers, and the Power between them as a Weight, it will eaſily be perceived, that when a Weight upon a Leaver is to be ſupported by a Power at each End, the Sum of the Powers muſt be equal to the Weight, and the Powers muſt be to each other in reciprocal Proportion of their Diſtances from the Weight.

The third Simple Machine is the Pulley.

That Pulley which the Rope runs over, is call'd an *Upper* Pulley; that under which the Rope runs, is call'd a *Lower* Pulley.

An Upper Pulley alters the Direction of the Power, but is of no farther Service; for upon the turning of the Pulley, the Velocities of the Weight and Power are equal, and conſequently their Quantities muſt be equal to conſtitute an *Æquilibrium.*

With a ſingle lower Pulley, the Power moves twice as faſt as the Weight; and therefore to make an *Æquilibrium*, the Weight muſt be double to the Power.

The Smalneſs or Largeneſs of the Pulley makes no Alteration in this Rule.

In any Combination of Pulleys where they all communicate with one another, the *Æquilibrium* will be, when the Power is to the Weight, as One to the Number of Strings at the lower Pulleys; for it is evident that the Velocities are in that Proportion, becauſe every String at the lower Pulleys muſt ſhorten, juſt as much as the Weight riſes; and the Power muſt deſcend, as much as is the Sum of the Shortnings of all the Strings.

In a Combination of ſeparate Pulleys, where each lower Pulley has its own peculiar String, the Power muſt be to the Weight, as One is to the Number Two continually doubled as many times as there are lower Pulleys.

In all Caſes, Allowance muſt be made for the Weight of the lower Pulleys.

The next Simple Machine is the Wheel and Axel: And here there will be an *Æquilibrium* when the Power is to the Weight, as the *Radius* of the Axel is to the *Radius* of the Wheel.

But if the Thickneſs of the Rope be conſiderable, the Semidiameter of the Rope muſt be added both to the *Radius* of the Wheel and to the *Radius* of the Axel. When the Rope begins to cover the Axel a ſecond time, three times the Semidiameter of the Rope muſt be added to the *Radius* of the

the Axel: When the Rope begins to cover the Axel a third time, five times the Semidiameter of the Rope muſt be added to the *Radius* of the Axel, *&c.*

Wherefore if we would work the Machine always with the ſame Velocity, the Power muſt be increaſed every time the Rope recedes from the Axel.

An inclined Plane is the laſt Simple Machine.

If a Weight be raiſed with an uniform Motion upon an inclined Plane, the Power that raiſes it muſt move the whole Length of the inclined Plane; but by the third Article of Machines in general, the Motion of the Weight is the Aſcent of its Center of Gravity: Therefore the Velocity of the Power is to the Velocity of the Weight, as the Length of the Plane to the perpendicular Height of the Plane.

Wherefore there will be an *Æquilibrium* upon the inclined Plane, when the Power which acts parallel to the Plane, is to the Weight, as the perpendicular Height of the Plane is to the Length of the Plane.

The whole Force with which a Weight deſcends in a right Line towards the Center of the Earth, is call'd the *Abſolute Gravity* of that Weight.

The diminiſh'd Force with which a Weight deſcends upon an inclined Plane, in an oblique Line towards the Center of the Earth, is call'd the *Relative Gravity* of that Weight upon the Plane.

If a Plane be perpendicular, the Relative Gravity upon it is equal to the Abſolute Gravity; but if a Plane be Horizontal, there is no Relative Gravity at all.

To move a Weight upon a Horizontal Plane with any Velocity, there is nothing wanting but a Force ſufficient to overcome Friction and the *Inertia* of Matter.

A Screw is nothing elſe but a Spiral inclin'd Plane encompaſſing a Cylinder; and therefore if the Power be to the Weight, as the Length of the Arbor to the Length of the Thread of the Screw, there ſhall be an *Æquilibrium.*

A Rectangular Wedge is nothing but an inclined Plane, where the Power muſt be conceiv'd to move ſo far as the Wedge enters; and the Weight muſt be conceiv'd to move ſo far as the Parts of the Wood are ſeparated by the entring of the Wedge.

Wherefore to make an *Æquilibrium*, the Power muſt be to the Weight, as the perpendicular Height of the Wedge to the Length of its Baſe.

A Wedge in the common Form is nothing but two Rectangular Wedges joined together at their Baſes; and therefore the Power and Weight in *Æquilibrio* will be to each other, as the Thickneſs of the Back of the Wedge is to the perpendicular Length of the Wedge meaſur'd from the dividing Edge to the Back.

In like manner, the Nature of all compound Machines is eaſily demonſtrated; for we have nothing elſe to do but to compute what would be the Proportion of the Velocities of the Weight and Power, and to take their Forces in reciprocal Proportion of thoſe Velocities.

All theſe Rules are demonſtrated to be true from the bare Conſideration of the Nature of Motion in general; and therefore if a Machine differs from the Rule, (as all Machines will differ more or leſs) the Difference muſt be aſcribed to Friction and the Reſiſtance of the Medium, or ſome Irregularity in the Structure of the Machine, or Imperfection in the Materials.

A more full and particular Account both of Simple and Compound Machines, may be ſeen in the little Treatiſe of Mechanicks publiſh'd by Mr. *Watts*.

Of the Laws of Motion.

THESE Laws relate to the Effects of Moving Forces, upon ſuch Bodies as are at Liberty to move without any Obſtacle or Reſiſtance.

The firſt Law of Motion.

ALL Bodies perſevere in their State of Reſt or uniform Motion in a right Line, unleſs by ſome impreſſed Force they are made to change that State.

We know by Experience, that it requires the ſame Force to deſtroy Motion as to produce it; therefore as all Bodies are inactive, ſo they can neither move, unleſs they are moved; nor ſtop, unleſs they are ſtopped by ſome Force impreſſed upon them.

All Motion is in its own Nature perpetual; but no Motion, how artfully ſoever contrived, can be in Fact perpetual, becauſe of the Reſiſtance of the Medium.

If a Body is impell'd at the ſame time by two equal Forces in contrary Directions, the Forces will deſtroy each others Effect, and the Body will remain at Reſt between them. And if a Body remains at Reſt between two

Forces that act upon it in contrary Directions, thoſe Forces ſhall be equal.

If the Forces are unequal, the Body will move in the Direction of the ſtrongeſt Force, in the ſame manner as if it were impell'd by a Force equal to the Difference of thoſe two Forces.

If the Sides of any Parallelogram repreſent the Proportion and Direction of two Forces acting upon the ſame Body at the ſame time, the Diagonal of that Parallelogram ſhall repreſent the Proportion and Direction of a ſingle Force, equivalent to both the former.

Upon this Principle any ſingle Force may be reſolv'd into many; and any Number of given Forces acting upon the ſame Point at the ſame time, may be reduced to one.

A moving Body cannot be made to deſcribe a Curve Line by any one Impulſe whatſoever.

If a Body having received one Impulſe moves in the Circumference of a Circle, it is attracted towards the Center of that Circle by a Force acting upon the Body every inſtant of its Motion: For in every Part of the Circumference, the revolving Body forſakes the right Line of its preſent Direction, and approaches towards the Center of the Circle.

Thus a Stone in a Sling revolves about the Hand, till the String is let go, and the Attraction ceaſes; then it immediately flies off in a Tangent to that Point of the Circumference in which the Stone happens to be.

Here are four Things to be conſidered:

1. The original Impulſe of the Stone.

2. The continual Attraction which draws away the Stone from moving in a right Line. This is call'd the Centripetal Force, that is, the Force which carries the Stone towards the Center.

3. The conſtant Tendency of the Stone to fly off in a Tangent, which ariſes from the Continuance of the Effect of the original Impulſe, according to this firſt Law of Motion. This is call'd the Projectile Force.

4. A certain Force which balances the Attraction, and prevents the Stone from falling to the Center. This is caus'd by the continual Effort which the Stone exerts to fly off from the Center in a Targent, and it is call'd the Centrifugal Force, that is, the Force which carries the Stone from the Center.

The Centripetal and Centrifugal Forces are always equal; for they act in contrary Directions, and deſtroy each others Effect, ſo that the Body neither flies off, nor falls in, but is carried on in its own proper Orbit.

Thus in the Sling, the Stone and the Hand pull againſt each other with an equal Force, the String being equally ſtretch'd between them.

If the Attraction continues the ſame, whilſt the Centrifugal Force becomes greater, the revolving Body ſhall recede from the Center; but if the Attraction continues the ſame, and the Centrifugal Force becomes leſs, the revolving Body ſhall approach towards the Center. If the Attraction entirely ceaſes, the Body ſhall fly off in a Tangent; and if the Projectile Force be quite deſtroy'd, the Centrifugal Force conſequently ceaſing, the Body ſhall fall in a direct Line to the Center.

Of the MOTIONS, DISTANCES, *and* PERIODS *of the* PLANETS.

THE Planets, if we conſider only their mean Motions, Diſtances, and Periods, are Bodies uniformly revolving in circular Orbits, whoſe common Center is the Sun.

That the Planets are not carried round by Vortices, is evident, becauſe being denſer than the Fluid of the Vortex, they could not revolve in an Orb, but muſt perpetually fly off from the Sun in a Spiral: For when two Bodies, whether ſolid or fluid, move about any Point as a Center, the denſeſt Body has always the greateſt Centrifugal Force.

That there are neither ſolid Orbs nor Vortices in the Solar Syſtem, is evident from the Motion of Comets which traverſe the Orbs of all the Planets almoſt in a right Line.

That the Reſiſtance of the Medium, in which the Planets move, is inconſiderable, is evident from the Continuance and Regularity of their Motions for ſo many Ages.

That the Planets are attracted by the Sun, is evident, becauſe they continually forſake the right Line of their preſent Direction, and approach towards the Sun.

That the Planets have alſo a Projectile Force, is evident, becauſe they don't tend towards the Sun in a right Line.

This Attraction and Projectile Force is ſufficient to explain the Motions of the Planets.

The Periods (in Hours) and Diſtances of the Planets from the Sun (in Miles) are as follows:

	Periods.	*Diſtances.*
Saturn,	258232	667,664200
Jupiter,	103980	364,081200
Mars,	16488	106,679300
The Earth,	8766	70,000000
Venus,	5393	50,633100
Mercury,	2111	27,097000

There is a wonderful Harmony, which was firſt obſerved by *Kepler*, between the Periods and Diſtances of the Planets; for the Squares of any two Numbers in the firſt Column, are proportional to the Cubes of the correſpondent Numbers in the ſecond Column; that is, the Squares of the Periodic Times are as the Cubes of the Diſtances.

Now all Bodies muſt of neceſſity obſerve this Law, if they revolve in Circles about one common Center, by means of a Centripetal and Projectile Force.

For the following Rules concerning Centripetal Forces are not only demonſtrable Geometrically, but are alſo proved by Experiment.

1. That if two Bodies revolve about different Centers, and if the Diſtances and Periodic Times are equal, the Centripetal Forces ſhall be as the Quantities of Matter in the revolving Bodies.

2. That if the Quantities of Matter and the Periodic Times are equal, the Centripetal Forces ſhall be as the Diſtances.

3. If the Quantities of Matter and Diſtances are equal, the Centripetal Forces ſhall be as the Squares of the Periodic Times reciprocally, or as the Squares of the Velocities directly.

4. If the Quantities of Matter and the Velocities are equal, the Centripetal Forces ſhall be as the Diſtances reciprocally.

5. Wherefore if only the Quantities of Matter are equal, the Centripetal Forces ſhall be in compound Proportion of the Diſtances reciprocally, and the Squares of the Velocities directly.

The ſame Rules are eaſily proved Geometrically; for when the Quantities of Matter are equal, the Centripetal Forces are as the verſed Sines of the Arches, which Bodies deſcribe in any given Inſtant of Time; but the verſed Sine of any Arch is equal to the Square of the Chord of that Arch, divided by the Diameter of the Circle; and in very ſmall Arches, the Chords and the Arches are equivalent. Therefore the Centripetal Forces are as the Squares of the Arches, divided by the Diameters of the Circle. Therefore the Centripetal Forces are as the Squares of the Velocities directly, and as the Diameters or Semidiameters reciprocally.

From the three firſt Rules it follows, that in all Caſes the Centripetal Forces are in compound Proportion of the Diſtances and Quantities of Matter directly, and the Squares of the Periodic Times reciprocally.

Now it has been already ſhewn concerning the Attraction of Gravitation, that the

Force is in all Caſes as the Quantity of Matter directly, and the Squares of the Diſtances reciprocally.

Wherefore if from both theſe Expreſſions of the ſame Force we take away the Quantity of Matter, and add to both the Square of the *Radius* and the Square of the Periodic Times, it will appear that the Squares of the Periodic Times are as the Cubes of the Diſtances.

Therefore an attracting and projectile Force are ſufficient to explain the Motions of the Planets in their Orbs; and conſequently, by the third Philoſophical Rule, thoſe Forces are the true natural Cauſes of the Planets Motions.

We cannot indeed be ſure that the Diſtances of the Planets contain juſt ſo many Miles as are aſſign'd to each in the foregoing Table; but yet Geometry will aſſure us, that thoſe Numbers in the Table expreſs the true *Proportions* of the Planets Diſtances; which is as ſufficient for our preſent Purpoſe, as if they expreſſed the real Diſtances themſelves.

The Moon revolves about the Earth from the ſame Cauſes that the Earth and other Planets revolve about the Sun, that is, by means of a Projectile Force and a Centripetal Force, which tends to the Center of the Earth.

Jupiter has four Moons or Satellites, in all which the Squares of the Periodic Times are proportional to the Cubes of their reſpective Diſtances from that Planet. Wherefore the Revolutions of theſe Satellites, or Secundary Planets, are of the ſame Nature with the Revolutions of the Primary Planets about the Sun; and therefore, by the ſecond Philoſophical Rule, we ought to aſſign the ſame Cauſes to both.

The ſame is to be underſtood of *Saturn* and his five Moons.

Each Planet has not only a progreſſive Motion in its Orbit, but alſo a Motion of Rotation about its own Axis, which occaſions an alternate Succeſſion of Night and Day to all its Inhabitants, if it has any.

The Sun himſelf in the Center of the Syſtem turns about his own Axis, finiſhing one Revolution in twenty five Days and a quarter.

The Circuit of the Earth's Equator is about 24000 Miles, and therefore at the Equator the Diurnal Rotation is at the rate of 1000 Miles an Hour; but the Earth's progreſſive Motion in her Orbit is about fifty times as faſt.

The Diurnal Rotation in the Parallel of *London* is at the Rate of 622 Miles an Hour.

Tho' the Earth's Diurnal Rotation be very ſwift at the Equator, yet it produces but a ſmall Centrifugal Force, (as appears from the 4th Rule concerning Centripetal Forces) becauſe the Diſtance from the Center is very great, almoſt 4000 Miles.

Wherefore ſuch Bodies as lie looſe upon the Surface of the Earth, will not be flung from it by the Diurnal Rotation; becauſe, as Sir *Iſaac Newton* has computed, the Weight of each Body is 289 times greater than its Centrifugal Force at the Equator.

From this firſt Law of Motion and its Corollary, it alſo follows, that Bodies flung into the Air, will in Appearance aſcend and deſcend in the ſame manner, ſuppoſing the Earth to move, as they would do ſuppoſing the Earth to be at Reſt.

The Second LAW *of* MOTION.

THE Alteration of Motion is always proportional to the moving Force impreſſed, and in the ſame Direction in which that Force is impreſſed.

The firſt Law regards only ſuch Motions as are uniform; the ſecond relates to accelerated and retarded Motions.

Of the Deſcent of Heavy Bodies in a direct Line.

IF a Body be made to move by any Force in any Direction, and be accelerated by the ſame Force in the ſame Direction every Inſtant of its Motion, the acquired Velocities ſhall be as the Times computed from the Beginning of the Motion. For if we conceive Time to be divided into infinitely ſmall Parts, which may be call'd *Inſtants*, the Number of Accelerations ſhall be equal to the Number of Inſtants; and therefore the Sum of the Inſtants, that is, the whole Time, ſhall be proportional to the Sum of the Accelerations, that is, to the laſt Velocity.

The Motion of a Body deſcending by its own Weight in a right Line near the Surface of the Earth, is ſuch a Motion as is here deſcribed. For tho' the Force of Gravity does indeed increaſe, as the Body deſcends; yet is that Augmentation of the attracting Force inſenſible and inconſiderable.

If a Body falls from a certain Height, and then moves uniformly with the laſt acquired Velocity, it ſhall move twice as far as it fell in the ſame Time that it ſpent in falling. For Example, let us ſuppoſe the Body to ſpend ſix Inſtants in its Fall, and to acquire ſix Degrees of Velocity, it is certain that the Line deſcribed in deſcending may fitly be expreſs'd by the Sum of the following Numbers;

0, 1, 2, 3 4, 5, 6

And the Line deſcribed by the uniform Motion, may fitly be expreſs'd by the Sum of the following Numbers;

6, 6, 6, 6, 6, 6, 6

Now the Sum of the laſt Series of Numbers is juſt double the Sum of the firſt Series, And the ſame thing will happen in all Caſes.

Wherefore if a Body that has fallen from a certain Height moves uniformly with half the laſt Velocity, it ſhall move juſt as far as it has fallen in the ſame Time that it ſpent in falling.

Thus the accelerated Motion of falling Bodies is reduced to the Caſe of an uniform Motion. Now in all uniform Motions, the Lines deſcribed are in compound Proportion of the Times and Velocities, by the firſt Rule concerning Motion and Reſt in general: But in the Caſe of falling Bodies, the Times are in the ſame Proportion with the Velocities; therefore the Lines deſcribed by falling Bodies are as the Squares of the Times.

Thus if the Time of falling be double, half the laſt Velocity ſhall be double; and twice the Velocity in twice the Time will carry the Body four times as far.

Bodies are obſerved to fall about 16 Feet in a Second of Time; therefore in 10 Seconds they will fall 1600 Feet, and in 60 Seconds 57620 Feet.

The Times or the Velocities of falling Bodies are in ſubduplicate Proportion, or as the ſquare Roots of the Lines deſcribed by their Fall.

If a Bullet be ſhot directly upwards, the Motion will be continually retarded by the Attractions of Gravity in a contrary Direction, till at laſt the whole Motion is deſtroy'd; then the Bullet ſhall begin to fall, and the Motion ſhall be accelerated in the ſame Time and in the ſame Manner as it was before retarded.

Wherefore the Velocities of the Bullet aſcending and deſcending ſhall be equal at equal Heights in all Parts of the Line.

If ſeveral Bullets are ſhot directly upwards with different Velocities, their greateſt Altitudes ſhall be as the Squares of thoſe Velocities; for in every Bullet, the Line of Aſcent and Deſcent is the ſame, and the firſt Velocity aſcending is equal to the laſt Velocity deſcending: But the Lines of Deſcent are as the Squares of the laſt Velocities deſcending; therefore the Lines of Aſcent are as the Squares of the Velocities aſcending.

Of the Motion of PROJECTILES.

IF a heavy Body be thrown in a horizontal or oblique Direction, it ſhall aſcend or deſcend juſt as it would do if it had no progreſſive Motion; and it ſhall at the ſame time advance by the progreſſive Motion, juſt in the ſame Manner as if it did not aſcend or deſcend at all.

Wherefore all Projectiles near the Surface of the Earth deſcribe *Parabolas*, from the Properties of which Figure the Rules of Gunnery may be demonſtrated Geometrically, as they are alſo ſhewn experimentally (making Allowance for the Reſiſtance of the Air) to be as follows;

1. The greateſt Random is at the Elevation of 45 Degrees.

2. If two Elevations are taken at equal Diſtances from 45 Degrees, one above, and the other below it, the Ranges ſhall be equal.

3. The greateſt Altitude of a perpendicular Projection is equal to half the greateſt Random. Theſe three Rules will be demonſtrated Geometrically when we come to treat of Spouting Fluids.

4. Wherefore as 16 Feet is to one Second of Time, ſo is half the greateſt Random to a fourth Number; the ſquare Root of which is the Number of Seconds ſpent in the Fall of the Projectile from its greateſt perpendicular Height at 90 Degrees Elevation.

5. If the Number of Feet in the greateſt Random be divided by the Number of Seconds found by the laſt Rule, the Quotient ſhall ſhew the Velocity of the Projection, or at the rate of how many Feet in a Second the Body would be carried by the impreſſed Force alone, according to the firſt Law of Motion: For in a perpendicular Projection, the laſt deſcending Velocity is equal to the Velocity impreſſed at firſt, and would carry the Body by an uniform Motion, in the time of its Fall, twice as far as it deſcended, that is, once the Length of the greateſt Random.

Thus the greateſt Random of a *Minion* is about 29300 Feet: Wherefore the Velocity impreſſed is almoſt 950 Feet in a Second of Time.

When Projectiles are thrown into the Air, the greateſt Random is at the Elevation of 44 Degrees and a half; the lower Ranges go farther than the upper correſpondent Ranges, and the greateſt Height of the perpendicular Projection is more than half the greateſt Random. All theſe Irregularities are occaſion'd by the Reſiſtance of the Medium.

Of RESISTING MEDIUMS.

THE Reſiſtance of Mediums is proportional to the Quantities of Motion which Bodies moving therein, loſe in any given Inſtant of Time.

There are two Sorts of Reſiſtance; one that ariſes from the Tenacity of the Medium, or the Friction and Attrition of its Parts; another that is owing to the *Inertia* of Matter.

The firſt Kind of Reſiſtance in any one Fluid will always be proportional to the Number of Parts of the Medium, which the moving Body ſeparates in a given Inſtant of Time. Therefore the Reſiſtance of the ſame Medium to the ſame Body moving with different Velocities, ſhall be as the Velocity of the Motion; and the Reſiſtance of the ſame Medium to different (ſpherical) Bodies moving with the ſame Velocity, ſhall be as the Diameter of the Body; for it muſt be proportional to the Surface of that Part of the Medium which is diſplaced by the moving Body. This Reſiſtance therefore in all Caſes is in compound Proportion of the Velocity and Diameter.

The other Kind of Reſiſtance is proportional to the Quantity of Motion, which the Medium receives from the moving Body in a given Inſtant of Time.

Therefore if equal Bodies move with equal Velocities in different Mediums, this ſort of Reſiſtance ſhall be proportional to the Denſity of the Medium. If equal Bodies move in the ſame Medium with different Velocities, it ſhall be as the Square of the Velocities; for the Velocity impreſs'd upon the Parts of the Medium, and the Number of Parts of the Medium upon which the Motion is impreſs'd in a given Inſtant, are both proportional to the Velocity of the moving Body: Therefore the Quantity of Motion impreſs'd is as the Square of the Velocity. But if unequal (ſpherical) Bodies move with the ſame Velocity in the ſame Medium, it is evident that the Reſiſtance ſhall be as the Area of a great Circle of the moving Sphere, that is, as the Square of its Diameter.

Wherefore in all Caſes, this ſecond Kind of Reſiſtance will be in compound Proportion of the Denſity of the Medium, and the Square of Velocity and the Square of the Diameter of the moving Body.

If a heavy Body deſcends in a reſiſting Medium, the Motion ſhall be accelerated, but not in the ſame manner as *in Vacuo*;

for *in Vacuo*, every Inſtant of Time produces an equal Acceleration; but in the Air, the Accelerations decreaſe continually, becauſe the Reſiſtance increaſes as the Square of the increaſing Velocity.

If a Body be thrown downwards, with ſuch a Velocity as ſhall make the Reſiſtance of the Medium equal to the Acceleration of Gravity, it will move on with an uniform Motion, according to the firſt Law.

The Velocity of a Body deſcending by its own Weight only in a reſiſting Medium, is always leſs than that Velocity which produces the uniform Motion, but continually approaching towards it.

Hence it is, that tho' *in Vacuo* all Bodies deſcend equally faſt, yet in reſiſting Mediums the heavieſt fall faſteſt.

Of the MOTION *of the* MOON *and* TIDES.

HAving ſeen by what Laws heavy Bodies deſcend towards the Center of the Earth, it will now appear very evidently, that the Attraction of Gravitation towards the Earth is ſufficient to draw the Moon continually from the Rectilineal Motion, according to the firſt Law, and to make her revolve in an Orbit, which has the Earth for its Center.

The Diameter of the Earth is 42107149 Feet; the Diameter of the Moon's Orbit is 60 times as much, or 2521028940 Feet; the Circumference of a great Circle of the Earth is 132000768 Feet; the Circumference of the Moon's Orbit is 60 times as much, or 7920046080 Feet. The Moon finiſhes one Period in her Orbit in 27 Days, 7 Hours, and 43 Minutes: Therefore in one Minute of Time, ſhe moves in her Orbit an Arch of 201307 Feet. Now the verſed Sine of any Arch is found by dividing the Square of the Chord of that Arch (or the Square of the Arch itſelf, if it be a very ſmall Arch) by the Diameter of the Circle. Wherefore if we divide the Square of 210307 by 2521028940, the Quotient ſhall give 16 Feet for the verſed Sine; and ſo far does the Moon in one Minute of Time forſake the Rectilineal Motion, by deſcending towards the Earth. But it has been ſhewn before, that near the Surface of the Earth, heavy Bodies deſcend 57620 Feet in a Minute of Time: Therefore at the Orb of the Moon, where the Diſtance is 60 times greater, and the Force of Attraction 3600 times leſs, Bodies will deſcend in one Minute of Time only $\frac{57620}{3600}$ or 16 Feet. Wherefore the Attraction of the Earth is ſufficient to make the Moon revolve in the Manner ſhe does revolve, and conſequently is the real Cauſe of her revolving in the Orbit.

We have all along ſuppoſed that Bodies deſcend at firſt near the Surface of the Earth 16 Feet in a Second of Time; but more accurately it is 16 Feet and 1 Inch.

It was firſt diſcovered by *Kepler*, from Aſtronomical Obſervations, that the Planets do not revolve about the Sun in Circles, but in Ellipſes, the Sun being not in the Center, but in one of the *Foci* of the Ellipſes.

That Part of the Orbit which is neareſt the Sun is called the *Perihelium*; that Part of the Orbit which is fartheſt from the Sun is called the *Aphelium*.

If the Original Impulſe upon a Planet was leſs than what was neceſſary to make the Centrifugal Force equal to the Centripetal, it would then revolve in an Ellipſis, whoſe Aphelion would be that Point of the Orb where the Revolution began.

If the Original Impulſe of a Planet was greater than what was neceſſary to make the Centrifugal Force equal to the Centripetal, it would then revolve in an Ellipſis whoſe *Perihelium* would be the Point from whence the Revolution began.

Let it be noted, that in both Caſes it is ſuppoſed, that the Direction of the impreſſed Impulſe is perpendicular to the Direction of the Attraction.

The ſame *Kepler*, before mention'd, diſcover'd likewiſe from Aſtronomical Obſervations, that a Ray drawn from the Center of the Sun to the Center of any Planet, deſcribes equal Areas in equal Times; and it is eaſy to ſhew that this muſt of neceſſity happen, if the Planets move by a Centripetal and Projectile Force.

What has been ſaid of the Planets revolving about the Sun, muſt alſo be applied to the Moon's revolving about the Earth; only that Part of the Orbit which is neareſt to the Earth is called the *Perigæum*, and that Part of the Orbit which is fartheſt from the Earth is called the *Apogæum*.

A Planet moves ſloweſt in the *Aphelium*, and faſteſt in the *Perihelium*, otherwiſe the Areas could not be equal. In moving from the *Aphelium* to the *Perihelium*, the Motion is accelerated by the Aſſiſtance of the Central Attraction: In moving from the *Perihelium* to the *Aphelium*, the Motion is retarded by the Oppoſition of the Central Attraction.

The more particularly theſe Principles are applied to the Motions of the Heavenly Bodies, the more exactly they will be found to anſwer the Phænomena in every Circumſtance.

The general Phænomena of the Tides may alſo be accounted for by the Attractions of the Sun and Moon.

By the *general* Phænomena of the Tides, are meant ſuch as happen in the wide Ocean, or rather ſuch as would happen if the whole Surface of the Earth were cover'd with Waters.

The general Phænomena of the Tides are,

1. That there happens two Tides in twenty four Hours and three Quarters.

2. That the Time of High Water is about three Hours after the Moon has left the Meridian, either above or below the Horizon.

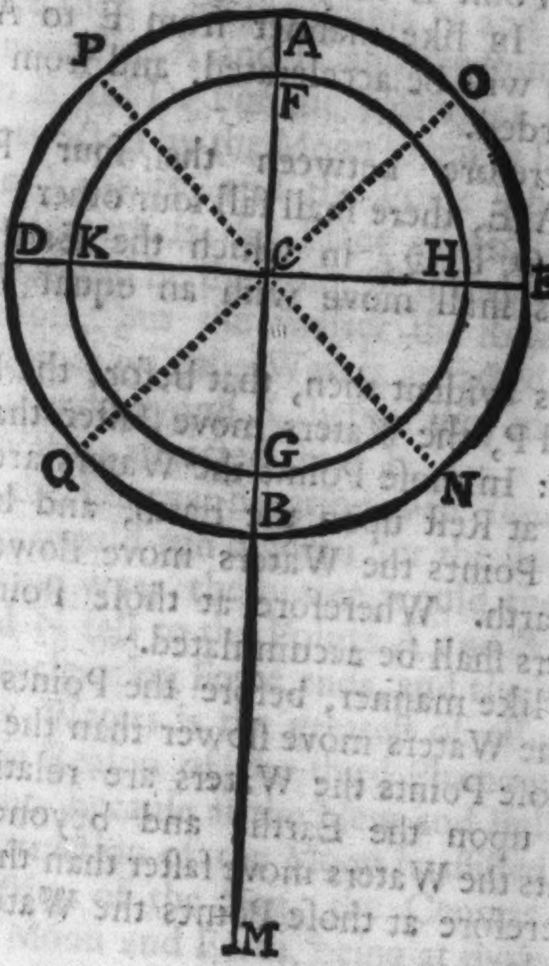
3. That the Tides are greater than ordinary twice every Month, that is, about the Time of the New and Full Moon: Theſe are called the Spring-Tides.

4. That the Tides are leſſer than ordinary twice every Month, that is, about the Times of the firſt and laſt Quarters of the Moon: Theſe are call'd the Neap-Tides.

5. That when the Moon is in her *Perigæum*, the Tides increaſe more than in the ſame Circumſtances at other times.

6. That all things conſidered, the Spring-Tides are greater in *March* and *September*, than at other times of the Year, and the Neap-Tides leſs.

Let ADBE repreſent the Surface of the Waters, FKGH the Surface of the Earth turning about its own Axis from F to K, G and H, and carrying the Waters along with it. Let C repreſent the Earth's Pole, M the Center of the Moon, MCA the Meridian of the Moon.



Now it is evident, that the Motion of the Waters, as they revolve from D to B, ſhall be accelerated by the Attraction of the Moon at M; ſo that at the Point B, the Waters ſhall move faſter than the Earth. But from B to E, the Motion of the Waters ſhall be retarded by the Attraction of the Moon, till at the Point E they move ſlower than the Earth. In like manner from E to A the Motion will be accelerated, and from A to D retarded.

Wherefore between the four Points D, B, A, E, there ſhall fall four other Points, as N, O, P, Q, in which the Earth and Waters ſhall move with an equal Velocity.

It is evident then, that before the Points N and P, the Waters move faſter than the Earth: In thoſe Points the Waters are relatively at Reſt upon the Earth, and beyond thoſe Points the Waters move ſlower than the Earth. Wherefore at thoſe Points the Waters ſhall be accumulated.

In like manner, before the Points O and Q, the Waters move ſlower than the Earth: In thoſe Points the Waters are relatively at Reſt upon the Earth, and beyond thoſe Points the Waters move faſter than the Earth. Wherefore at thoſe Points the Waters ſhall ſubſide.

Wherefore N P are the Points of High Water, being about three Hours beyond the Moon's Meridian, and O Q are the Points of Low Water.

If the Diurnal Rotation were ſwifter than it is, the Points N and P would fall nearer to E and D, and the Points O and Q to A and B. If the Diurnal Rotation were ſlower than it is, the Points N and P would fall nearer to A and B, and the Points O and Q to E and D. For the Waters at D and E are attracted by the Moon towards B with an equal Velocity, and the Point where they would meet is the Place of High Water. This would be the Point B, if there were no Rotation; but the ſwifter the Rotation is, the farther will the Waters attracted from D be carried beyond B, before they meet with the Waters attracted from E.

If the Diurnal Rotation were ſlower, the Tides would run higher; for the ſlower the Rotation was, the nearer would the Points P and N fall to the Points A and B, where the accelerating Force ends, and the Velocity of the Waters is the greateſt of all.

The Reaſon of the third Phænomenon is evident, becauſe at the New and Full Moon the Attraction of the Moon is aſſiſted by the Attraction of the Sun, the Centers of the Sun, Moon and Earth, being at thoſe Times nearly in a right Line.

The Reaſon of the fourth Phænomenon is alſo evident, becauſe in the Quarters of the Moon the Sun accelerates where the Moon retards, and retards where the Moon accelerates.

Only it muſt be obſerved, that the Spring-Tides happen not preſently upon the New and Full Moons, but rather one or two Days after, when the Attraction of the Sun has conſpired with the Attraction of the Moon for ſome conſiderable time. In like manner, the Neap-Tides happen a Day or two after the Quarters, when the Attraction of the Sun has continued to leſſen the Effect of the Moon's Attraction for ſeveral Days together.

The fifth Phænomenon is a plain Conſequence of the Increaſe of the Moon's Attraction upon her nearer Approach towards the Earth. At the Spring-Tides in *March* and *September*, the Sun and Moon deſcribe a great Circle, and therefore produce a ſwifter, and conſequently a greater Agitation of the Waters: But at the Neap-Tides in *March* and *September*, the Moon deſcribes a ſmall Circle, which produces a ſmaller Agitation of the Waters; and the Sun deſcribes a great Circle, which takes off more from the Attraction of the Moon, and makes the Agitation ſtill leſs.

As the Motion of the Waters is accelerated and retarded by the Attraction of the Moon, ſo in like manner the Motion of the Moon is accelerated and retarded by the Attraction of the Sun, which is the Cauſe of the Inequalities of the Motions of that Secundary Planet.

Of Oblique DESCENTS *and* PENDULUMS.

IT remains only to apply this ſecond Law of Motion to the Deſcent of heavy Bodies upon inclined Planes, and the Motion of *Pendulums*.

Now upon inclined Planes, it is evident that Bodies ſhall deſcend by the ſame Laws as they do in direct Lines, only allowing for the Difference between the Abſolute and Relative Gravity. Hence the following Rules for Oblique Deſcents may be deduced.

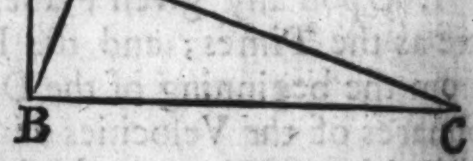
1. Upon any given Plane, the Velocities are as the Times; and the Lines deſcribed from the beginning of the Deſcent are as the Squares of the Velocities or Times, and the Velocities or Times in ſubduplicate Proportion of the Lines deſcribed.

2. The laſt Velocity acquired by the direct Deſcent is to the laſt Velocity acquired in the ſame Time by the oblique Deſcent,

as

as the Abſolute Gravity is to the Relative Gravity; for the Accelerations from the Beginning to the End of the Deſcent are all the way in that Proportion; and the Number of the Accelerations is the ſame in both Caſes, becauſe the Times are ſuppoſed equal. Therefore the Sums of the Accelerations, and conſequently the laſt Velocities, are alſo as the Abſolute Gravity to the Relative Gravity, or as the Length of the Plane to the perpendicular Height of the Plane.

3. The Line deſcribed by the direct Deſcent, is to the Line deſcribed in the ſame Time by the oblique Deſcent, as the Length of the Plane to the perpendicular Height of the Plane; for the laſt Velocities are in that Proportion by the ſecond Rule, and the Lines deſcribed in the ſame Time are as the laſt Velocities.



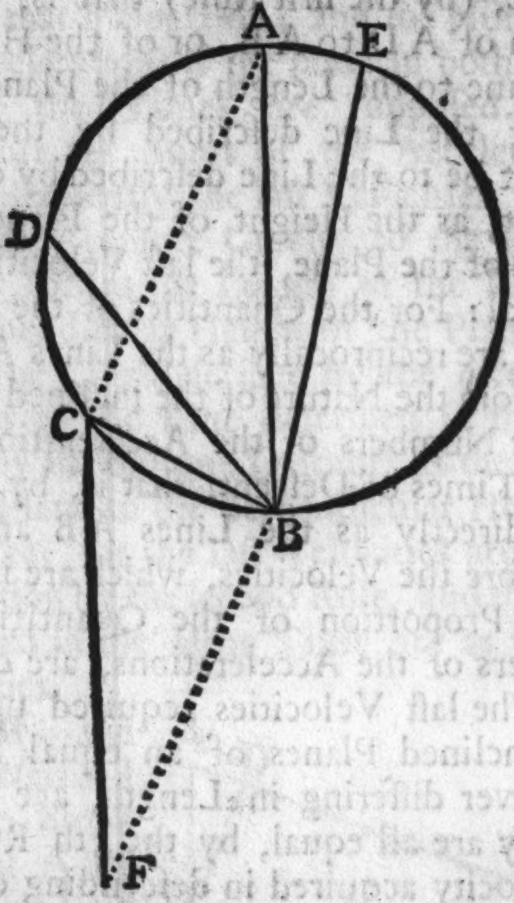
4. If the Line deſcribed by the direct Deſcent A B, be to the Line deſcribed by the oblique Deſcent A C, as the Height of the Plane to the Length of the Plane, then the Times of Deſcent ſhall alſo be in that Proportion: For drawing B D at right Angles to A C, in the Points D and B the Times of

Deſcent ſhall be equal by the third Rule; and in the Points D and C, the Times of Deſcent ſhall be in ſubduplicate Proportion of A D to A C, (by the firſt Rule) that is, in Proportion of A D to A B, or of the Height of the Plane to the Length of the Plane.

5. If the Line deſcribed by the direct Deſcent be to the Line deſcribed by oblique Deſcent, as the Height of the Plane to the Length of the Plane, the laſt Velocities ſhall be equal: For the Quantities of the Accelerations are reciprocally as the Lines A B and A C, from the Nature of the inclined Plane; and the Numbers of the Accelerations are as the Times of Deſcent, that is, by the 4th Rule, directly as the Lines A B and A C. Therefore the Velocities, which are in compound Proportion of the Quantities and Numbers of the Accelerations, are equal.

6. The laſt Velocities acquired upon ſeveral inclined Planes of an equal Height, howſoever differing in Length, are equal: For they are all equal, by the 5th Rule, to the Velocity acquired in deſcending directly thro' the perpendicular Height of the Plane. In like manner, the Times of Deſcent are as the Lengths of the Planes by the 4th Rule.

7. The Time of an oblique Deſcent along the Chord of any Circle, drawn from the loweſt Point of the Circle, is equal to the

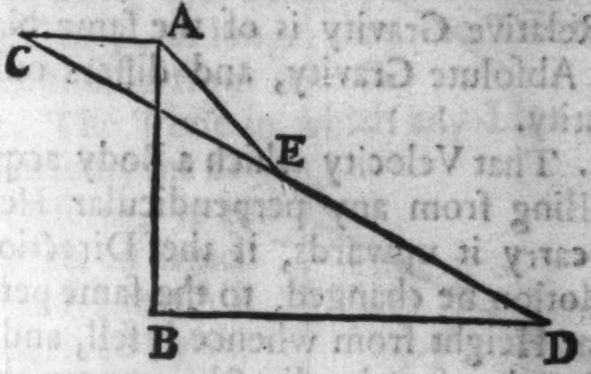


Time of a direct Deſcent thro' the Diameter of that Circle. For drawing B F at right Angles to C B, the Times at B and at F ſhall be equal, (by the third Rule) and C F is equal to A B from the Nature of the Circle.

8. The Times of oblique Deſcent thro' ſeveral Chords CB, DB, EB, are all equal.

9. Hence it follows, that the Relative Gravities of any given Body upon the ſeveral Chords CB, DB, EB, are as thoſe Chords.

10. A Body deſcending from a certain perpendicular Height, ſhall acquire the ſame Velocity, whether it deſcends directly, or on an oblique Plane, or upon ſeveral oblique Planes. For let AB be the perpendicular



Height of the Plane CD, and of the two Planes AE, ED, a Body deſcending firſt from A to B, and then from C to D, ſhall acquire the ſame Velocity in B and D by Rule the 5th. And deſcending firſt from A to E, and then from C to E, it ſhall acquire the ſame Velocity in E. Therefore it ſhall acquire the ſame Velocity in deſcending thro' AED, as in deſcending thro' CED.

11. The laſt acquired Velocities of a Body deſcending to the loweſt Point of a given Circle, through different Chords, ſhall be as thoſe Chords: For the Times of Deſcent are equal by the 8th Rule, and the Relative Gravities are as the Chords by the 9th Rule; and the Velocities acquired in equal Times, are as the Relative Gravities, as is evident from the 2d Rule.

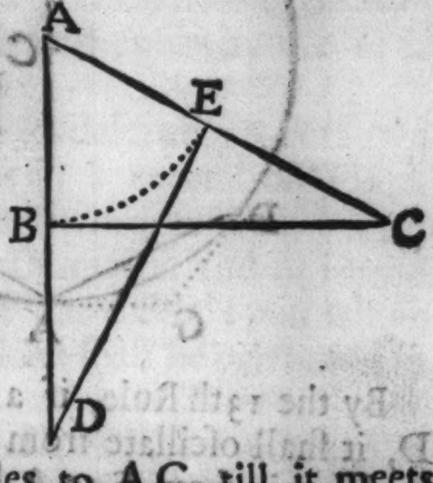
12. All Bodies, howſoever differing in Weight, deſcend upon a given Plane in the ſame Time and with the ſame Velocity: For Relative Gravity is of the ſame Nature with Abſolute Gravity, and differs only in Quantity.

13. That Velocity which a Body acquires by falling from any perpendicular Height, will carry it upwards, if the Direction of the Motion be changed, to the ſame perpendicular Height from whence it fell, and that whether it aſcends directly, or upon an oblique Plane, or upon ſeveral oblique Planes. For it is evident, that as the Velocity which was acquired by falling directly from A to B, will carry the Body back from B to A; ſo the Velocity acquired by deſcending from C to D, will carry back the Body from D to C; and the Velocity acquired by deſcending from A to E and D, will carry back the Body from D to E and A. Now theſe three

Velocities are all equal by the 10th Rule: Therefore the ſame Velocity which was acquired by falling in any one of thoſe three Lines, will carry the Body back to the ſame perpendicular Height, either in the ſame Line in which it deſcended, or in any other Line.

14. A Body ſhall deſcend in leſs time from A to E and D, than from C to E and D. For in both Caſes, the ſame Time will be ſpent in deſcending from E to D; and by the 8th Rule, the Time ſpent in deſcending from C to E, is longer than the Time ſpent in deſcending from A to E.

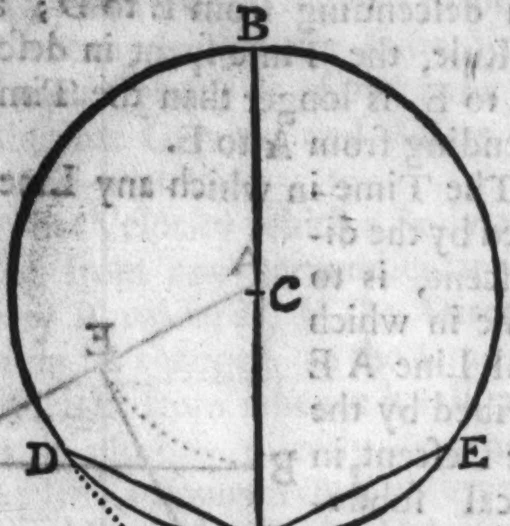
15. The Time in which any Line AB is deſcribed by the direct Deſcent, is to the Time in which an equal Line AE is deſcribed by the oblique Deſcent, in reciprocal ſubduplicate Proportion of the Abſolute Gravity to the Relative Gravity. Draw ED at right Angles to AC, till it meets AB produced in D. Now by the third Rule, the Times of Deſcent in D and E are equal; but the Times in B and D are in ſubduplicate



cate Proportion of AB to AD. Therefore the Times of Deſcent in B and E are in ſubduplicate Proportion of A B to A D, that is, of A B to A C.

Any Motion which is firſt produced by a continual Acceleration, and then deſtroyed by a continual Retardation, is called *Oſcillation.*

Let D A, E A, be two equal Chords in the Circle B E A D.



By the 13th Rule, if a Body be placed at D, it ſhall oſcillate from D to A and E, and back again from E to A and D.

The Time of oblique Deſcent ſhall be equal to the Time of oblique Aſcent, and each equal to the Time of direct Deſcent from B to A by the 7th Rule.

Therefore the Time of an entire Oſcillation ſhall be equal to twice the Time of direct Deſcent thro' B A, or equal to the Time of direct Deſcent thro' four times B A.

And the Time of Oſcillation thro' any other two Chords of the ſame Circle, ſhall be the ſame.

And becauſe the Times of direct Deſcent are in ſubduplicate Proportion of the Lines; therefore in different Circles the Times of Oſcillation are in ſubduplicate Proportion of four times the Diameters, that is, in ſubduplicate Proportion of the Diameters or Semidiameters.

In Chords of the ſame Circle, the Times of Oſcillation of all Bodies, howſoever differing in Weight, are all equal by the 12th Rule.

All Bodies begin to deſcend 16 Feet one Inch, or 193 Inches in a Second of Time. Therefore 48 Inches (which is the 4th Part of 193) ſhall be the Diameter, and 24 Inches the Semidiameter of the Circle upon whoſe Chords the Oſcillations ſhall be perform'd in a Second of Time.

If the Chords A D, A E, be taken very ſmall, they will differ but very little from the Arches of the Circle, and C A may be conſidered as a Pendulum oſcillating in thoſe Arches. Wherefore,

1. The ſame Pendulum ſhall oſcillate thro' unequal Arches in the ſame Time.

2. Pendulums of equal Lengths and unequal Weights ſhall oſcillate in the ſame Time.

3. The Times of Oſcillation in different Pendulums, are in ſubduplicate Proportion of the Lengths of the Pendulum.

If the Oſcillations of a Pendulum were perform'd in a Cycloide inſtead of a Circle, theſe three Laws of Oſcillation would hold true in large Arches, as well as in ſmall, as Mr. *Huygens* has demonſtrated.

The Length of a Pendulum oſcillating Seconds in a Cycloide, is 39 Inches and a quarter, and a Pendulum of the ſame Length ſhall alſo oſcillate Seconds in ſmall Arches of a Circle; for the lower Part of the Circle is nearly the ſame with the lower Part of the Cycloide.

If from D and A two Tangents are drawn interſecting each other in G, the Relative Gravity at the Point D upon the Chord is to the Relative Gravity at the Point D in the Circle, as D G to D A; which is the Reaſon why in thoſe ſmall Arches of a Circle the Oſcillations are ſwifter than along the Chords.

If an Iron Bar be ſuſpended at one End, and put into Motion, the Oſcillations ſhall be performed in leſs time than by a ſingle Pendulum of the ſame Length: For the upper Parts of the Iron ſhall endeavour to oſcillate according to their reſpective Diſtances from the Center of Suſpenſion, and ſo accelerate the Motion.

A ſingle Pendulum, whoſe Length is two Thirds of the Bar's Length, will be found to perform its Oſcillations in equal Times with the Bar. Hence a Point taken $\frac{1}{3}$ of the Length of the Bar from the lower End, is called the Center of Oſcillation, and is nearly the ſame with the Center of Percuſſion.

All oſcillating Bodies, of what Shape ſoever, have their proper Centers of Oſcillation; which if the Rod of the Pendulum be ſmall, and the Bob large, ſhall fall within the Bob.

By the Length of a Pendulum, is always meant the Diſtance between the Center of Suſpenſion and the Center of Oſcillation.

If a Pendulum be heated, it grows longer, and conſequently oſcillates ſlower.

Pendulums of the ſame Length oſcillate ſlower the nearer they are brought to the Equator, and that for two Reaſons; becauſe the Semidiameter of the Earth's Equator is about 17 Miles longer than the Semiaxis of the Earth; and becauſe of the Centrifugal Force (ariſing from the Diurnal Rotation) which at the Equator is the $\frac{1}{289}$ Part of Gravity,

vity, from whence it decreaſes continually, till at the Pales it quite vaniſhes.

It may eaſily be concluded from the 9th Rule of oblique Deſcents, that if a Pendulum oſcillate in ſmall Arches of a Circle, the Accelerations continually decreaſe, (tho' the Velocity continually increaſes) as the Diſtance from the loweſt Point of the Oſcillation decreaſes.

Therefore all Motions which are produced by continual Accelerations, decreaſing as the Diſtance decreaſes, from a certain Point towards which the Motion tends, may be compared to the Motion of a Pendulum; and of this Nature is the Motion of Waves.

The Third LAW *of* MOTION.

ACTION is always contrary and equal to Reaction; or the Actions of two Bodies upon each other are always equal and in contrary Directions.

Whatſoever draws, preſſes, or attracts, is at the ſame Inſtant drawn, preſſed, or attracted with an equal Force.

The Equality of Action and Reaction is to be judged, not from the Velocities, but from the Quantities of Motion produced by each of them.

If the Diſtance of the Sun from the Earth be 70 Millions of Statute Miles, the Diameters of the Heavenly Bodies may be judged to be as follows:

Of the *Sun*,	652,000
Of *Saturn*,	52,100
Of *Jupiter*,	69,200
Of *Mars*,	3,790
Of the *Earth*,	7,960
Of the *Moon*,	1,850
Of *Venus*,	6,750
Of *Mercury*,	3,630

From hence it may be gathered, that the Sun is not much affected by the Attractions of the Planets; becauſe ſuch Planets as are near the Sun are ſmall, and the bigger Planets are at a great Diſtance, and the Diameter of the Sun is almoſt ten times greater than the Diameter of the greateſt Planet.

The Breadth of *Saturn*'s Ring ſeems to be equal to the Diſtance between the Body of *Saturn* and the inner Part of the Ring, and that Diſtance ſeems to be about two Thirds of the Diameter of *Saturn*.

If one Body ſtrikes upon another, juſt ſo much Motion as it impreſſes in one Direction, juſt ſo much it loſes in the contrary Direction; and this is the grand Principle upon which all the Laws of the Communication of Motion depend.

The Laws of the Communication of Motion cannot be truly ſtated, without diſtinguiſhing Elaſtick Bodies from thoſe that are not Elaſtick.

Of ELASTICITY.

A Body that receives no Impreſſion, is called a Hard Body.

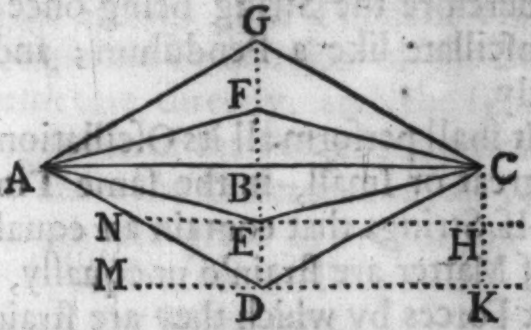
That which receives and retains an Impreſſion, is called a Soft Body.

That which receives an Impreſſion, but does not retain it, is called an *Elaſtick* Body; and if the Force of Reſtitution be equal to the Force of Compreſſion, it is ſaid to be *perfectly elaſtick*.

Re-action differs from Elaſticity; for Re-action begins and ends with the acting Force; but Elaſticity does not begin to exert itſelf, till the Force of Action is over.

If a String be ſtrained like thoſe of a Muſical Inſtrument, it ſhall become elaſtick or ſpringy; for the ſmalleſt Force ſhall be ſufficient to bend it, tho' it be ſtrained never ſo hard; and when that Force ceaſes, the Force that ſtrains it, ſhall bring it back to its firſt Situation.

As the String returns to its firſt Situation, it is continually accelerated, by a Force decreaſing as the Diſtance of the String from its firſt Situation decreaſes. For let A B C repreſent the String in its firſt Situation, A D C the String bent, and A E C the String returning: It is evident that D C and D E may be conſider'd as two Leavers of the ſecond Kind, in which C is the Center of Motion; the Force that ſtrains the String is the Power, and the Quantity of Matter to be moved (or the Quantity of Matter in D C or E C) anſwers to the Weight. Wherefore from the Center of Motion C, letting fall the Perpendicular C H K to the Lines of Direction, the Forces of the Power upon the two Leavers ſhall be as C K and C H, that is, as B D and B E, the Diſtances of the String from its firſt Situation.



When the Point D arrives at B, the Acceleration ceaſes; and as the laſt acquired Velocity carries the String beyond B towards

G, ſo a Retardation begins exactly proportional to the former Acceleration.

Wherefore the String being once moved, ſhall oſcillate like a Pendulum; and conſequently,

1. It ſhall perform all its Oſcillations, whether great or ſmall, in the ſame Time.

2. If Strings that contain an equal Quantity of Matter are ſtrain'd unequally, the different Forces by which they are ſtrain'd may be compared to an Abſolute and a Relative Gravity; and therefore by the 15th Rule of oblique Deſcents, the Times of Oſcillation ſhall be reciprocally in ſubduplicate Proportion of the ſtraining Forces.

3. In Pendulums, the Quantity of Matter is not regarded, becauſe whatever it be, it is always proportional to the Force (of Gravity) which cauſes the Oſcillation: But in Vibrating Strings equally ſtrain'd, the Times of Oſcillation are as the Quantities of Matter in the String. For when thoſe Strings are bent equally, the moving Forces ſhall be equal, and conſequently the Velocities ſhall be reciprocally as the Quantities of Matter, and the Times reciprocally as the Velocities, that is, directly as the Quantities of Matter. Wherefore,

4. In Strings that are ſtrained equally, if the Diameters are equal, the Times are as

the Lengths: If the Lengths are equal, the Times are as the Diameters.

5. In all Strings, the Times of Vibration are in compound Proportion of the Lengths and Diameters directly, and the ſubduplicate Proportion of the Forces reciprocally.

Hence ariſes the Difference of all Muſical Notes which are grave in Proportion to the Quickneſs, and acute in Proportion to the Slowneſs of the Vibrations.

The Sounds of two Strings vibrating at the ſame time, agree with each other more or leſs, according as the Vibrations concurr more or leſs frequently. This is the Origine of Concords and Diſcords in Muſick.

Two Strings of an equal Diameter being equally ſtrained; if they are of the ſame Length, ſhall ſound an Uniſon, and ſhall concurr at every Vibration.

If their Lengths are as two to one, they ſhall ſound a Diapaſon or Octave; and every Vibration of the longeſt ſhall concurr with every other Vibration of the ſhorteſt.

If their Lengths are as three to two, they ſhall ſound a Diapente or Fifth; and every other Vibration of the longeſt ſhall concurr with every third Vibration of the ſhorteſt.

If their Lengths are as four to three, they ſhall ſound a Diateſſeron or Fourth; and every third Vibration of the longeſt ſhall concurr with every fourth of the ſhorteſt.

If their Lengths are as five to four, they ſhall ſound a Ditone or greater Third; and every fourth Vibration of the longeſt ſhall concurr with every fifth of the ſhorteſt.

Theſe are all the perfect ſimple Concords; nor are any other Proportions admitted in Muſick, but ſuch as are taken from the Numbers 1, 2, 3, 4, 5, or their Compounds.

Other Lengths, in which the Vibrations concurr leſs frequently, produce ſuch Sounds as are reckon'd either imperfect Concords or Diſcords. The Frequency of concurring is to be computed from the Number of Vibrations of the longeſt String, which are performed before the Concurrence happens.

To make an Uniſon Sound, it does not ſeem neceſſary that the Vibrations ſhould actually concurr, but only that they ſhould be performed in an equal Time; ſo that they would concurr always, if they began exactly at the ſame Inſtant: For the Ear perceives not the ſingle Vibrations, but only a certain Sound which is the Reſult of repeated Vibrations. The like qualified Senſe of the Word *Concurrence* muſt be applied to the Diapaſon, and other Concords and Diſcords.

If a Body in Motion ſtrikes upon a ſtrained String, it ſhall rebound in an Angle equal to that in which it came: For ſo much of the Impulſe as is parallel to the String, ſhall continue; and ſo much of the Impulſe as is perpendicular to the String, ſhall be deſtroyed by the Oppoſition, and produced again by the Elaſticity.

All Bodies which, when ſtruck, give a Muſical Sound, do vibrate either in the Whole or in Part; and moſt Elaſtick Bodies, when ſtruck, give a muſical Sound; and the Reaſon why ſome do not, ſeems to be either becauſe the Spring is too weak, and the Motion too ſlow, as in the Caſe of compreſſed Wool; or becauſe the Elaſticity is ſo ſtrong, and the vibrating Parts ſo ſhort, and the Sound ſo acute and ſo ſoon over, that it cannot be perceived by the Ear, which perhaps is the Caſe in the Colliſion of two Glaſs Balls.

The Cauſe of Elaſticity in moſt Bodies ſeems to be the Repulſive Force of its Particles: For when the Elaſtick Body is compreſſed, its Pores are thereby contracted and made ſmaller; ſo that many Particles, which were at ſome Diſtance before, are now brought nearer together within the Sphere of each other's Repulſion; which Repulſion grows ſtronger as the Compreſſion increaſes, and the Particles are forced cloſer to each other. Wherefore, if the Pores of a Body are very large, it may admitt of Compreſſion without much Elaſticity. And hence alſo we ſee the Reaſon why the Elaſticity of Metals is increaſed by hammering.

It is certain from Experiments, that if Bodies rebound after Colliſion, one or both of them are Elaſtick; and hence it is that the Angle of Rebounding is always equal to the Angle of Incidence, when the moving Body ſtrikes againſt an Obſtacle which is conſider'd as immovable.

An Obſtacle is conſider'd as immovable, when the Quantity of Matter it contains is *infinite*, or *as infinite*, with regard to the Quantity of Matter contain'd in the moving Body; for then the Velocity impreſſed upon the Obſtacle will be *Nothing*, or as *Nothing*. For whatever that Velocity be, which a moving Body would impreſs upon another Body at Reſt equal to itſelf, the Velocity which the ſame moving Body would impreſs upon the infinite Obſtacle, would be infinitely leſs than the former Velocity.

Of the Communication of MOTION.

THoſe *Laws*, according to which Alterations are produced in the Reſt and Motion of Bodies upon their Colliſion, are called the *Laws of the Communication of Motion*.

When one Body ſtrikes againſt another, if the Line of Direction of the Impulſe paſſes thro' the Center of Gravity of both the Bodies, the Impulſe is called *full* or *direct*, otherwiſe it is called an oblique Impulſe.

The Relative Velocity of two Bodies is that Velocity with which they approach to, or recede from each other, and is equal either to the Difference of the Velocities of Bodies moving the ſame way, or to the Sum of the Velocities of Bodies moving contrary ways. For if one of the Bodies were at Reſt, and the other moved towards it, or from it with the fore-mentioned Difference or Sum of Velocities, the Body in Motion would approach to, or recede from the Body at Reſt, juſt as faſt as the two moving Bodies approached to, or receded from each other.

If two Bodies move in the ſame Direction with equal Velocities, they are relatively at Reſt.

When the Impulſe is direct, and the Bodies are void of Elaſticity, the Laws of the Communication of Motion are theſe that follow:

1. In all Caſes, the Velocities after the Stroak are equal; for the Impulſe ceaſes when the impinging Bodies are relatively at Reſt, and not before.

2. If two Bodies move the ſame way, and in the ſame right Line, that which moves faſteſt ſhall overtake the other, and the Sum of their Motions ſhall be the ſame after the

Stroak as before. For by the third Law of Motion, ſo much Motion as the ſloweſt Body gains, the ſwifteſt Body loſes.

3. If two Bodies move contrary ways, the Sum of their Motions after the Stroak ſhall be equal to the Difference of their Motions before the Stroak: For whilſt the ſtrongeſt Motion deſtroys the weakeſt, it loſes alſo an equal Part of itſelf by the third Law of Motion.

4. If the Sum of two conſpiring Motions, or the Difference of two contrary Motions, be divided by the Sum of the Quantities of Matter in both the moving Bodies, the Quotient ſhall give their common Velocity after the Stroak.

5. If the Velocity after the Stroak be multiplied into the Quantity of Matter in each Body, the Products ſhall expreſs the Quantities of Motion in each Body after the Stroak.

6. The Difference between the Quantities of Motion in either of the moving Bodies, before and after the Stroak, is equal to the Quantity of the Stroak.

Example 1. Let a Ball of 3 Ounces, moving with 9 Degrees of Velocity, overtake another Ball of 2 Ounces moving with 4 Degrees of Velocity: Then ſhall the Quantities of Motion before the Stroak be 27 and 8, the common Velocity after the Stroak ſhall be 7, the Quantities of Motion after the Stroak ſhall be 21 and 14, and the Quantity of the Stroak ſhall be 6.

Example 2. Let the ſame Balls move with the ſame Velocities contrary ways; then ſhall the Quantities of Motion before the Stroak be as before; the common Velocity after the Stroak ſhall be 3 and $\frac{4}{5}$, the Quantities of Motion after the Stroak ſhall be 11 and $\frac{2}{5}$, and 7 and $\frac{3}{5}$, and the Quantity of the Stroak 15 and $\frac{3}{5}$.

Wherefore, if two equal Bodies move in contrary Directions with equal Velocities, as ſoon as they ſtrike, both the Motions ſhall be deſtroy'd. And if a Body in Motion ſtrikes againſt an equal Body at Reſt, it ſhall communicate half its Velocity, or half its Motion. And if one moving Body overtakes another moving Body equal to the firſt, the common Velocity after the Stroak ſhall be equal to Half the Difference of their Velocities before the Stroak. But if they moved in contrary Directions, the Velocity after the Stroak ſhall be equal to Half the Sum of the Velocities before the Stroak.

7. If a moving Body ſtrikes againſt an immovable Obſtacle, after the Stroak the whole Motion ſhall be deſtroy'd, and the Quantity of the Stroak ſhall be equal to the whole Quantity of the Motion.

8. If the moving Body gravitates towards the immovable Obſtacle, (as when a Stone falls upon the Earth) the Quantity of the Stroak is equal to the Sum of the Quantity of Motion added to the Weight of the moving Body; for the Weight remains upon the Obſtacle when the Impulſe is deſtroy'd.

It was for want of this neceſſary Diſtinction, that the famous *Borelli*, in his Treatiſe *de Vi Percuſſionis*, attempts to prove (in effect) that the Impulſe of a Feather is a greater Force than the Weight of a Rock, *Cap.* 29. *Prop.* 90.

The Sum of the Motions of two Bodies void of Elaſticity, may be leſs after the Stroak than it was before, but it can't be more.

9. If a Body moves after the Stroak the ſame way that it moved before, the Difference of the Velocities before and after the Stroak ſhall be equal to the Velocity loſt or gain'd. Thus in the firſt Example, the Velocity loſt is 2, and the Velocity gain'd 3.

10. If the Direction of the Motion after the Stroak be contrary to the Direction of the Motion before the Stroak, the Sum of the Velocities before and after the Stroak ſhall expreſs the Quantity of the Velocity loſt. Thus in the 2d Example, the Velocities loſt are 5 and $\frac{1}{5}$, and 7 and $\frac{4}{5}$. For a Bo-

dy may be ſaid to loſe more Velocity than it has, when after its whole Velocity is deſtroy'd, a new Velocity is produced in a contrary Direction.

When the Impulſe is direct, and the Bodies perfectly elaſtick, the Laws of the Communication of Motion are different from the foregoing. For,

1. Upon the Colliſion of two Elaſtick Bodies, the Force of Elaſticity is equal to the Force of Compreſſion; and the Force of Compreſſion in each Body is equal to the Quantity of the Stroak.

2. The whole Force of Elaſticity, exerted at the Reſtitution of both the Springs, is double to the Quantity of the Stroak; for it is the Reſult of two Forces in contrary Directions, each of which is equal to the Quantity of the Stroak. Or it may be conceived thus; the Sum of the Elaſticities is equal to the Sum of the Quantities of the Stroak in both Bodies together; that is, to double the Quantity of the Stroak in each ſingle Body.

3. The Effect of the Elaſticity in each Body ſhall be equal to the Effect of the Stroak, and in the ſame Direction; for the two equal and contrary Elaſticities in the former Caſe are equivalent to Action and Re-action in the latter.

4. Wherefore, to find the Velocity of either Body after the Colliſion: Firſt, find the common Velocity with which the Bodies would move after the Stroak, if they had been void of Elaſticity, and find alſo the Velocity loſt or gain'd; then ſubſtract the Velocity loſt from the common Velocity, or to the common Velocity add the Velocity gain'd; ſo ſhall that Difference or Sum be the Velocity ſought; but if the Velocity loſt be greater than the common Velocity, then ſubſtract the common Velocity from the Velocity loſt, and the Remainder ſhall give the Velocity ſought in a contrary Direction.

Thus in the firſt Example before ſtated, if we ſuppoſe the Bodies to be Elaſtick, the Velocities after Colliſion ſhall be 5 and 10, and conſequently the Quantities of Motion ſhall be 15 and 20.

In the ſecond Example, the Velocities after Colliſion ſhall be 1 and $\frac{2}{5}$, and 4; and the Quantities of Motion 4 and $\frac{1}{5}$, and 8.

For a third Example; let us ſuppoſe two Bodies in Proportion as three to two, the firſt at Reſt, and the ſecond moving towards the firſt with 40 Degrees of Velocity; then ſhall the Quantities of Motion before the Stroak be 0 and 80, the common Velocity after the Stroak 16, the Quantities of Motion after the Stroak 48 and 32, the Quantity of the

Stroak 32, the Velocity gained 16, the Velocity loſt 24, the Velocities after the Reſtitution of the Springs 32, and 8 in a contrary Direction; the Quantities of Motion after Colliſion 96 and 16.

In the firſt Example, the Sum of the Motions before Colliſion is equal to the Sum of the Motions after Colliſion; in the ſecond it is greater, in the third leſs. This demonſtrates the Abſurdity of *Carteſius*'s Notion, "That there is always the ſame Quantity "of Motion in the World.

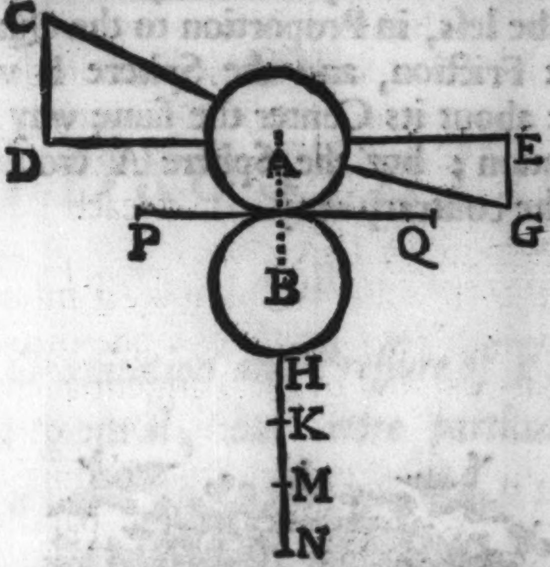
If two equal Elaſtick Bodies move towards each other with equal Velocities, they ſhall recede from each other after Colliſion each with the ſame Velocity. If one of them in Motion ſtrikes againſt the other at Reſt, it ſhall communicate the whole Velocity, and remain at Reſt itſelf. If one overtakes the other, they ſhall interchange Velocities, and continue to go on the ſame way as before. If they meet each other with different Velocities, they ſhall interchange Velocities, and fly off from each other in contrary Directions.

If an Elaſtick Body ſtrikes upon an immovable Elaſtick Obſtacle, it ſhall rebound with the ſame Velocity that it came.

If one of the impinging Bodies be hard, and the other elaſtick, the Laws of the Communication of Motion are the ſame as if both the Bodies were elaſtick; for the Spring will give way, till the Force of Elaſticity becomes equal to the Force of Compreſſion, that is, double to the Quantity of the Stroak in each Body; and the Re-action of a hard Body againſt double the Quantity of Elaſticity, will produce the ſame Effect as a ſingle Quantity of Elaſticity in each Body acting in contrary Directions.

If the Impulſe is oblique, it muſt be reſolved into two Impulſes; one direct, and the other parallel to the Tangent at the Point of Colliſion. The Effect of the direct Impulſe muſt be computed according to the Laws before-mentioned: The parallel Impulſe will continue after the Colliſion the ſame in all reſpects that it was before; nor will it produce any other Effect, except by means of the Friction to make the Bodies revolve each about its own Center of Gravity.

Example. Let the Spherical Body B, being at Reſt, be ſtruck by the equal Spherical Body A, moving with a Direction and Velocity expreſs'd by the Line C A, deſcribed in any given Time. Let the Motion C A be reſolved into the Velocities and Directions C D, D A; the Line C D being parallel to A B, which connects the two Centers of Gravity at the Inſtant of Colliſion; and the Line D A being parallel to the Tangent P Q, or rather to a Plane (repreſented by the Line PQ) touching both the Spheres in the Point



of Colliſion. Since the parallel Motion ſuffers no Alteration by the Impulſe, if the Line DA be continued, till AE is equal to DA, the Line AE ſhall repreſent the parallel Motion after Colliſion; and if the Spheres are both void of Elaſticity, half the Motion CD ſhall be communicated by the Impulſe. Wherefore, if we draw EG and HK parallel to CD, and reſpectively equal to half CD, then AG, HK, ſhall repreſent the Directions and Velocities after the Stroak. But if the Spheres are elaſtick, the whole Motion CD ſhall be communicated; and therefore if we take HM equal to CD, the Lines

AE, HM, ſhall expreſs the Directions and Velocities after Colliſion.

If there were any Friction, the Line AE would be leſs, in Proportion to the Quantity of that Friction, and the Sphere B would revolve about its Center the ſame way with the Motion; but the Sphere A would revolve the contrary way.

OF
HYDROSTATICS:
OR,
The Gravitation and Pressure of FLUIDS *in general, but more particularly of* INCOMPRESSIBLE FLUIDS.

A Fluid is a Body whoſe Parts are capable of moving ſo eaſily among one another, that they give way to any Force whatever that acts upon them.

To conſtitute a *Perfect* or *Philoſophical* Fluid, (which perhaps is not to be found in Nature) it is neceſſary that the Parts be not held together by mutual Attractions, nor obſtructed in their Motions by Friction or mutual Attritions.

However, if a Body is compoſed of Parts whoſe mutual Attractions and Attritions are but very ſmall, it is *vulgarly called* a Fluid.

Tho' the Laws of Hydroſtaſtics are deduced from the Philoſophical Notion of a Fluid, yet if thoſe Laws be applied to Vulgar Fluids, the Error will be but very ſmall.

If the Original conſtituent Parts of a Fluid do already touch each other in ſo many Points, that they cannot be brought nearer together without being divided into leſſer Parts; and if no known Force is great enough to divide them into leſſer Parts, ſuch a Fluid is called a *Compreſſed* or an *Incompreſſible* Fluid.

For Example; Water, Oil, and Mercury, are vulgar Fluids of the Incompreſſible Kind.

The Surface of any Fluid that is permitted to ſtagnate, will be level; for if one Part ſhould remain higher than another, it would thereby reſiſt the Force of Gravity which tends to make it deſcend, and conſequently would not be a Fluid.

All Fluids gravitate upon the Bottom of a Cylindrical Veſſel in which they are contain'd, in the ſame manner that Solids gravitate, that is, in Proportion to the Quantity of Matter.

Any Part of a Fluid gravitates according to its Quantity of Matter upon the reſt of the Fluid that lies below it: For if the upper Part did not gravitate according to its Quantity of Matter upon the under, the whole Fluid could not gravitate according to its whole Quantity of Matter upon the Bottom of the Veſſel.

Accordingly it is found by Experiment, that if a Veſſel be filled with Water, a Pint of that Water in any Part of the Veſſel ſhall weigh about a Pound, which is juſt as much as it weighs when taken out of the Veſſel.

In like manner, a Veſſel which contains about 24 Pints or Pounds of Water, is found to contain about 33 Hundredth Parts of an Ounce of common Air. This proves the Specific Gravities of Air and Water to be as 1 to about 850.

It is evident therefore, that in a Cylindrical Veſſel, the Gravitation of any Fluid is proportionable to the Depth or Diſtance from the Surface.

If any Part of the Fluid be forced down below the Surface; when the Force is taken away, that Part which was forced down ſhall aſcend, and place itſelf even with the Surface.

Therefore in every Part of the Fluid, there is a Preſſure upwards, equal to the Preſſure of Gravitation in that Part of the Fluid.

It is alſo clear from Experiments, that in every Part of the Fluid there is a Preſſure, equal to Gravitation, in all manner of Directions.

Wherefore, ſince every Part of the Fluid is acted upon in all manner of Directions by an equal Force, every Part of a ſtagnating Fluid is at Reſt, and will ſo continue till it is diſturbed by ſome external Force.

Conſequently, tho' every Part of the Fluid gravitates according to its Depth, yet no one Part preponderates or gravitates more than the reſt.

If a new Preſſure be added to any Part of the Surface, the Column of Fluid that lies under that Part ſhall deſcend, and become ſhorter, till the Sum of the additional Preſſure, and the Preſſure of the ſhorten'd Column, ſhall be equal to the Preſſure of an entire Column upon the like Baſe in any other Part of the Fluid.

If the Preſſure of any Column be leſſen'd, or its Weight diminiſh'd, that Column ſhall aſcend and become longer, till the Preſſure of the increaſed Column becomes equal to the Preſſure of an entire Column upon the like Baſe in any other Part of the Fluid.

Fluids of different Kinds gravitate upon each other according to their perpendicular Heights and SpecificGravit ies.

Every Part of the Veſſel, which contains a Fluid, ſuſtains an equal Preſſure with that Part of the Fluid to which it is contiguous.

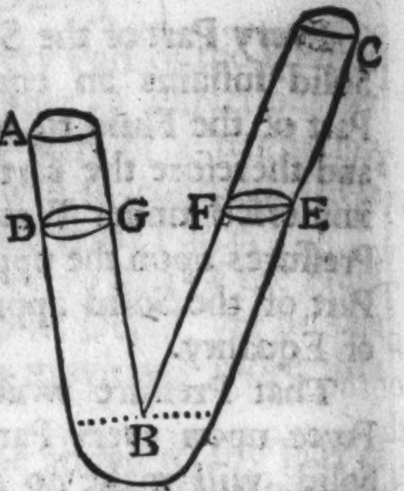
Every Part of the Surface of an immerſed Solid ſuſtains an equal Preſſure with that Part of the Fluid to which it is contiguous; and therefore the farther that any Solid is immerſed under Water, the nearer do the Preſſures upon the upper Part and the under Part of the Solid approach to a Proportion of Equality.

That Preſſure which acts with an equal Force upon every Part of the Surface of a Solid, will make no Alteration in the Surface, howſoever ſoft or ſuſceptible of Impreſſion it may be. Hence it follows, that tho' the Preſſure of the Water at great Depths is very conſiderable, yet it is hardly perceptible.

The Preſſure of any Fluid may be ſo far augmented, by augmenting the Depth or Diſtance from the Surface[, as to ſuſtain Quickſilver or Gold, or any other Fluid or Solid whatſoever; for the Solid or Denſe Fluid cannot preſs upon any thing with more than its whole Weight.

The Weight of an Incumbent Fluid will keep down a Body ſpecifically lighter than itſelf, provided it does not inſinuate itſelf between the Solid and the Bottom of the Veſſel.

Let

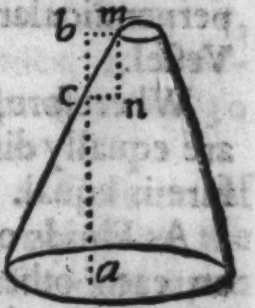


Let A B, B C, be two Cylindrical Veſſels or Tubes of an equal Diameter communicating with each other at B, and let A B be placed perpendicularly, and B C in an oblique Situation; If Water be pour'd into ſuch a Veſſel, the Surfaces in both Tubes ſhall ſtand in the ſame Level, or at the ſame perpendicular Altitude, as at D G and F E. For the Abſolute Gravity of the Water B E is to the Abſolute Gravity of the Water B D, as B F to B G; and the Abſolute Gravity of the Water B E is to its own Relative Gravity, as B G to B F. Therefore the Abſolute Gravity of the Water B D is equal to the Relative Gravity of the Water B E.

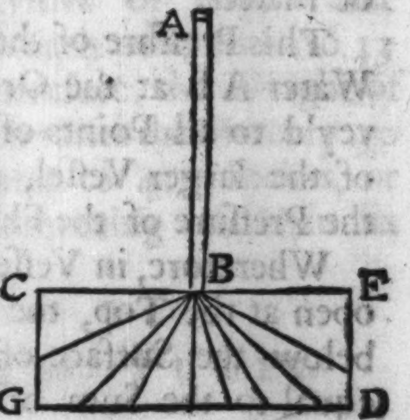
If a Veſſel be bigger at the Top than at the Bottom, the Preſſure upon the Bottom ſhall be equal to the Preſſure of a Column of Water whoſe Baſe is equal to the Bottom of the Veſſel, and whoſe Height is equal to the perpendicular Height of the Water in the Veſſel: For the Preſſure of all the reſt of the Water is ſuſtained by the oblique Sides of the Veſſel.

Wherefore, if two Cylinders of *unequal* Diameters are joined together, the Water, or any other Fluid, ſhall ſtand at the ſame Level in both.

If a Veſſel bigger at the Bottom than at Top be filled with Water, the Bottom of the Veſſel ſhall ſuſtain as great a Preſſure, as it would do, if the Veſſel were as big at the Top as it is at the Bottom: For the Preſſure of the Water againſt the Side of the Veſſel at *c*, is equal to the Gravitation of the Water at the Depth *m n* or *b c*; and the Re-action of the Side at *c*, is equal to the Preſſure, and in contrary Directions. Therefore the Re-action of the Side of the Veſſel at *c*, is equivalent to the Gravitation of the Water at the Depth *b c*. Therefore the Point *a* is preſſed by the Line *c a*, as much as it would be preſſed by the Line *b a*.



Let A B repreſent a ſmall Tube fix'd in a large Veſſel C D, and let the whole be filled with Water to the upper Oriſice at A. It is evident that the little Column A B preſſes upon all Parts of the larger Veſſel at the ſame time;



time, becauſe it preſſes in all Directions at the ſame time.

Wherefore, in all Caſes, the Preſſure of any Fluid upon the Bottom of the Veſſel, is equal to the Preſſure of a Column of the ſame Fluid, whoſe Baſe is equal to the Bottom of the Veſſel, and Height equal to the perpendicular Height of the Fluid in the Veſſel.

Wherefore, in all Points of the Fluid that are equally diſtant from the Surface, the Preſſure is equal.

As Fluids of different Kinds gravitate upon each other according to the reſpective Quantities of Matter they contain, ſo the Atmoſphere, or Body of groſs Air with which the Earth is ſurrounded, gravitates upon the Surface of all other Fluids, with a certain determinate Force proportional to its Quantity of Matter.

This Preſſure of the Atmoſphere upon the Water A B at the Orifice A, ſhall be convey'd to all Points of the Bottom and Sides of the larger Veſſel, in the ſame manner as the Preſſure of the Fluid A B is conveyed.

Wherefore, in Veſſels of all Kinds that are open at the Top, the Preſſure at all Depths below the Surface of a contain'd Fluid is equal to the Sum of the Preſſures of the Fluid and Atmoſphere.

If one End of an open Tube be immerſed in Quickſilver, and the Air be exhauſted at the other End by ſucking with the Mouth, or any other Means, ſo that within the Tube a *Vacuum* be made, and the Preſſure of the Atmoſphere taken away; the Preſſure of the Atmoſphere without will force the Quickſilver into the Tube, and there ſuſpend it, ſo long as the *Vacuum* continues, at a determinate perpendicular Height of about 30 Inches.

Wherefore, the Weight of a Column of Quickſilver 30 Inches high, is equal to the Weight of a Column of Air ſtanding upon an equal Baſe, and whoſe Height is equal to the whole Height of the Atmoſphere.

Hence it is clear, that the Quickſilver will ſtand at the ſame Height in Tubes of all Diameters.

The Specific Gravities of Rain-Water and Quickſilver are to each other as 1 to 13 and two Thirds. Wherefore, the Weight of the Atmoſphere which raiſes the Mercury 30 Inches, will raiſe Water to 410 Inches, or about 34 Feet, or ſomething leſs than ſix Fathoms.

Of SIPHONS and PUMPS.

ALL manner of Hydraulic Engines depend upon theſe Principles.

Hence it is, that a Siphon always works on that Side which has the greateſt perpendicular Altitude: For the Preſſure of the Atmoſphere equally opposes the Deſcent of the Water in both Legs of the Siphon; ſo that there is nothing left to determine the Motion of the Water one way or other, but the ſuperior Preſſure of the Water in one of the Legs; which ſuperior Preſſure is the Effect of a greater perpendicular Altitude.

If the perpendicular Altitude of a Siphon, from its Bend to the Surface of the Water, be ſix Fathom or more, the Siphon cannot be filled by Suction, or any other Method of exhauſting the Air; and if it be filled firſt, the Water will ſeparate at the Bend, Part of it running out at each Orifice; becauſe when ſuch a Siphon is full, the Weight of Water in each Leg is greater than the Preſſure of the Atmoſphere.

The ſame thing will happen, if we attempt to draw off Quickſilver with a Siphon whoſe perpendicular Altitude is 30 Inches or more.

From theſe Principles we may perceive the Reaſon of the Conſtruction and Working of common Pumps, and why they can raiſe Water no higher than about ſix Fathoms.

That Siphons and Pumps may work freely, it is always neceſſary that there ſhould be a *Vent* or Paſſage for the Air to enter into the Veſſel, and fill up the Place of the Liquor as it is drawn off; otherwiſe the Preſſure of the Air upon the Surface will continually decreaſe, and at laſt become too weak to force the Liquor thro' the Pump or Siphon.

How the Preſſure of the Air decreaſes in Proportion to its Expanſion, or the Quantity of Space which it finds empty, will be ſhewn hereafter.

Of SPOUTING WATER.

AN Artificial Jet or Spout of Water is called a Fountain.

The Rules for Spouting Liquors are theſe that follow:

1. The Force which makes the Water ſpout thro' a Hole in the containing Veſſel, is proportional to the Depth of the Hole, or its Diſtance from the Surface of the Water in the Veſſel: For the Preſſure of the Water upon that Part of the Veſſel before the Hole was made, was equal to the Sum of the Preſſures of the Water and Atmoſphere; but as ſoon as the Hole is made, the Spouting of the Water is oppoſed by the Preſſure of the Atmoſphere againſt the Hole. The Force therefore with which the Water ſpouts, is only the Preſſure of the Water, which in all Points is proportional to its Depth.

2. The Quantities of Water ſpouting in the ſame Time thro' equal Holes with different uniform Velocities, ſhall be proportional to thoſe Velocities.

3. The Quantities of Motion paſſing thro' ſeveral equal Holes in the ſame Time, are in compound Proportion of the Velocities and Quantities of Matter; that is, by the ſecond Rule, as the Squares of the Velocities, or of the Quantities of Water.

4. The Forces are proportional to their Effects, that is, to the Quantities of Motion generated in the ſame Time; that is, by the third Rule, to the Squares of the Velocities, or of the Quantities of Water. Therefore by the firſt Rule, the Depths are as the Squares of the Velocities, or of the Quantities of Water.

5. Therefore, the Quantities of Water paſſing thro' equal Holes in the ſame Time, are in ſubduplicate Proportion (or as the Square Roots) of the Depths.

6. The Velocity of any Drop of Water ſpouting thro' any given Hole, ſhall be equal to that Velocity which it would acquire in falling perpendicularly from Reſt thro' a Line equal to the Depth of the Hole: For at the Beginning, the Spouting and the Falling Drop are both accelerated by the ſame Force, that is, its own Gravity; and therefore, their Velocities are equal at firſt, and they continue equal afterwards, becauſe they

both increaſe according to the ſame Law: For the Velocities of both are all the way in ſubduplicate Proportion of the Depths.

7. Tho' Water will riſe in Pipes as high as the Surface of the Head from whence it falls; yet in perpendicular Jets it can never riſe quite ſo high, becauſe of the Reſiſtance of the Air, and the Friction of the Adjutage.

8. The Reſiſtance of the Air is ſo much the more conſiderable, becauſe of the different Directions of the Preſſure by which the Water is thrown up. For the Water moving towards the Hole of the Adjutage in different Directions, ſhall go out in the ſame Directions; and therefore cannot aſcend in one continued Column, but is ſeparated and ſcattered, and broken into ſmall Threads, each of which aſcends and deſcends by itſelf independently of all the reſt; and ſo the Effect of the Air's Reſiſtance becomes more ſenſible, as in the tenth Rule.

9. The Scattering of the Jet, and the Reſiſtance of the Air, may be remedied in Part by the Form of the Adjutage. A Tube or concave Cylinder ſeems the propereſt Shape to take off the Lateral Preſſures; but then the Greatneſs of the Friction both ſhortens the Jet, and makes it irregular. The moſt convenient Form of an Adjutage is a Tube cover'd with a thin Plate, in which there is made a ſmooth well poliſh'd Hole, leſs than

the Cavity of the Tube. For in ſuch an Adjutage, the Water will acquire an aſcending Direction in the Body of the Tube, and will find but ſmall Friction in paſſing by the thin Plate, and will go out in a regular Shape thro' the poliſh'd Hole.

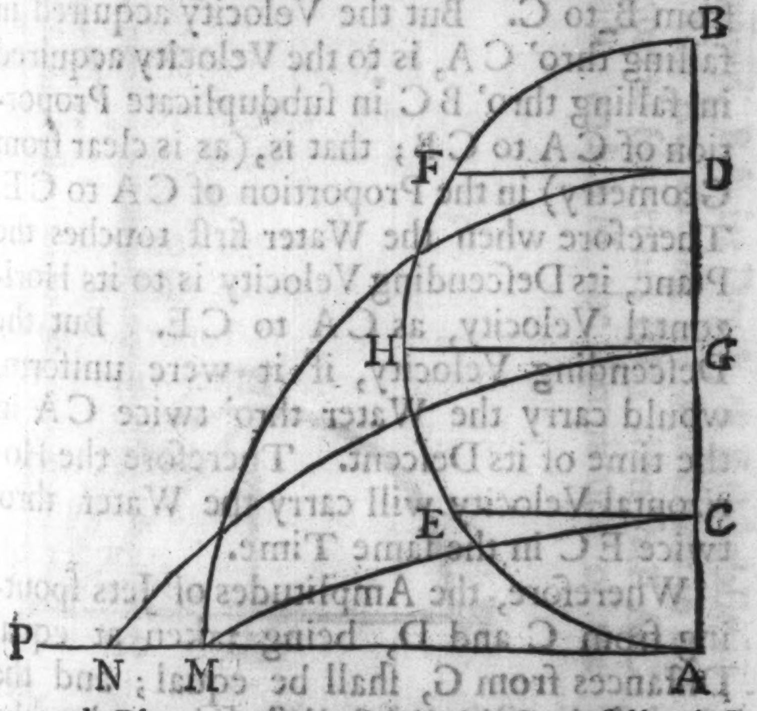
10. The Height of the Water in the Reſervoir continuing the ſame, the Quantity of the Friction of the Adjutage is proportional to the Surface of Metal which is contiguous to the Spouting Water; that is, it is proportional to the Diameter of the Hole; but the Quantity of Motion paſſing thro' the Hole in any given Time, is as the Area of the Hole, that is, in duplicate Proportion of the Diameter of the Hole. Therefore, the Effect of the Friction ſhall be leſs, as the Hole of the Adjutage is larger.

11. The Conduit, or Pipe conveying the Water from the Reſervoir to the Adjutage, ought to be very large, in Proportion to the Aperture of the Adjutage; otherwiſe the Water will deſcend in the Conduit with a ſenſible Velocity, and therefore meet with a ſenſible Reſiſtance, whereby the Impulſe of the deſcending Water will be conſiderably leſs than its Preſſure before it deſcended.

12. The Velocity of Water deſcending thro' a Hole in the Bottom of the Veſſel, will be greater than the Velocity of a Horizontal Jet ſpouting from the ſame Depth;

and the Velocity of the Horizontal Jet will be greater than the Velocity of a Perpendicular Jet: For in the firſt Caſe, the Velocity of the Water is accelerated by its own Weight, and that Acceleration is communicated to the neighbouring Parts by mutual Attraction. In the third Caſe, the Retardation of the Water that is paſs'd the Adjutage, is an Obſtacle to that which is paſſing.

13. If we ſuppoſe Water to ſpout without Friction or Reſiſtance, the Amplitudes of all Horizontal Jets may be determined in the following manner: Let A P be a Horizontal Plane upon which the Jets fall, A B the Height of the Surface of the Water in

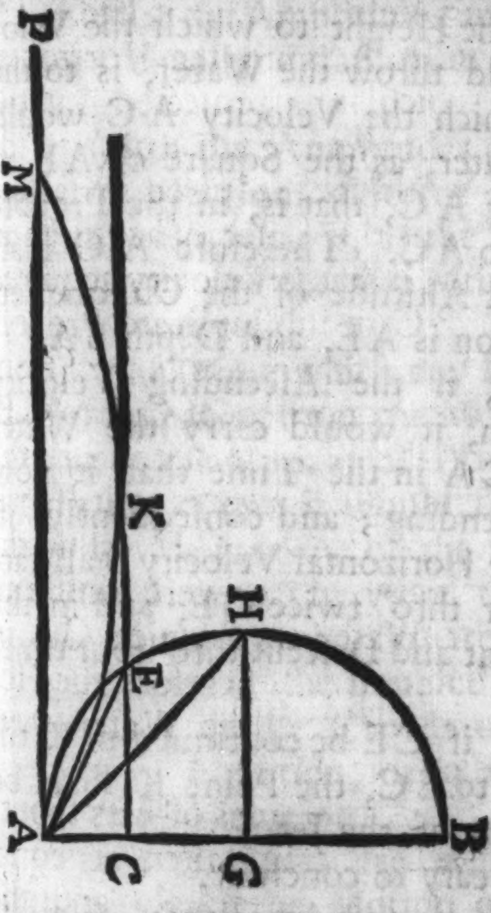


the Reſervoir above that Horizontal Plane; B C the Depth of any given Hole where the Water ſpouts. On B A, as a Diameter, deſcribe the Semicircle B H A, draw C E parallel to A P, and make A M double to E C; then ſhall M A be the Amplitude of the Water ſpouting from the Hole C. For the Water will fall upon the Plane A P with the ſame deſcending Velocity, as if it had fallen directly from C to A; and the Horizontal Velocity with which it is projected by the Preſſure, is equal (by the ſixth Rule) to the Velocity that would be acquired in falling from B to C. But the Velocity acquired in falling thro' C A, is to the Velocity acquired in falling thro' B C in ſubduplicate Proportion of C A to C B; that is, (as is clear from Geometry) in the Proportion of C A to C E. Therefore when the Water firſt touches the Plane, its Deſcending Velocity is to its Horizontal Velocity, as C A to C E. But the Deſcending Velocity, if it were uniform, would carry the Water thro' twice C A in the time of its Deſcent. Therefore the Horizontal Velocity will carry the Water thro' twice E C in the ſame Time.

Wherefore, the Amplitudes of Jets ſpouting from C and D, being taken at equal Diſtances from G, ſhall be equal; and the greateſt Amplitude of all ſhall be, when the Hole is equally diſtant from the Horizontal

Plane, and the Surface of the Water in the Reſervoir; and that greateſt Amplitude AN ſhall be equal to AB, the Height of the Water in the Reſervoir above the Horizontal Plane.

14. By a like Conſtruction, the Altitudes and Amplitudes of oblique Jets may be determin'd. Let A be the Hole from whence the Jett is thrown, BA its Depth, AE the oblique Direction of the Jet, cutting the Semicircle in E; make AM equal to four times CE; then ſhall AC be the Altitude, and AM the Amplitude of the oblique Jet.



Let AE repreſent the oblique Velocity with which the Water paſſes thro' the Mouth of the Adjutage, then ſhall A C repreſent the Aſcending Velocity, and C E the Horizontal Velocity.

It is certain from the 7th Rule, that the Velocity A E would throw the Water in a perpendicular Jet from A to B; and it is alſo certain, from what has been demonſtrated concerning the Aſcent and Deſcent of heavy Bodies, that the Height to which the Velocity A E would throw the Water, is to the Height to which the Velocity A C would throw the Water, as the Square of A E to the Square of A C, that is, in the Proportion of A B to A C. Therefore A C ſhall be the greateſt Altitude of the Oblique Jet, whoſe Direction is A E, and Depth B A.

Wherefore, if the Aſcending Velocity were uniform, it would carry the Water thro' twice C A in the Time that it now ſpends in aſcending; and conſequently, in that Time the Horizontal Velocity ſhall carry the Water thro' twice C E, and in the Time of Aſcent and Deſcent thro' four times C E.

Wherefore, if C E be continued to K, till E K is equal to E C, the Point K ſhall be the higheſt Part of the Jet.

Hence it is eaſy to conclude,

1. That the greateſt Amplitude of all is in the Direction A H, that is, of 45 Degrees.

2. That the greateſt Amplitude is twice the Height of a perpendicular Jet, thrown from the ſame Depth.

3. That ſince the Arch EA is double to the Angle of Elevation EAM, therefore the Altitudes at different Angles are as the Verſed Sines, and the Amplitudes as the Sines, of twice the Angles of Elevation.

4. That the Amplitudes are equal at Elevations equally diſtant from 45 Degrees on each ſide.

5. That the Amplitudes of Jets at the ſame Angle from different Depths, are as thoſe Depths, that is, as the Squares of the Velocities; and that the Altitudes are alſo in that Proportion.

6. The Time which any Drop of Water ſpends in paſſing from the Mouth of the Adjutage to the Horizontal Plane, is equal to twice the Time it would ſpend in falling thro' the Verſed Sine of the doubled Angle of Elevation. Therefore the Times are proportional to the Square Roots of the Verſed Sines of the doubled Angles of Elevation, or to the Chords of the doubled Angles of Elevation, or to the Sines of the Angles of Elevation.

Theſe ſix Rules are alſo applicable to Gunnery and the Motion of Projectiles, if inſtead of *Jets ſpouting from the ſame Depth*, we put, *Projectiles thrown with an equal Velocity*;

locity;

locity; and in the room of *Jets ſpouting from different Depths*, we ſubſtitute, *Projectiles thrown with different Velocities*.

Of RUNNING WATER.

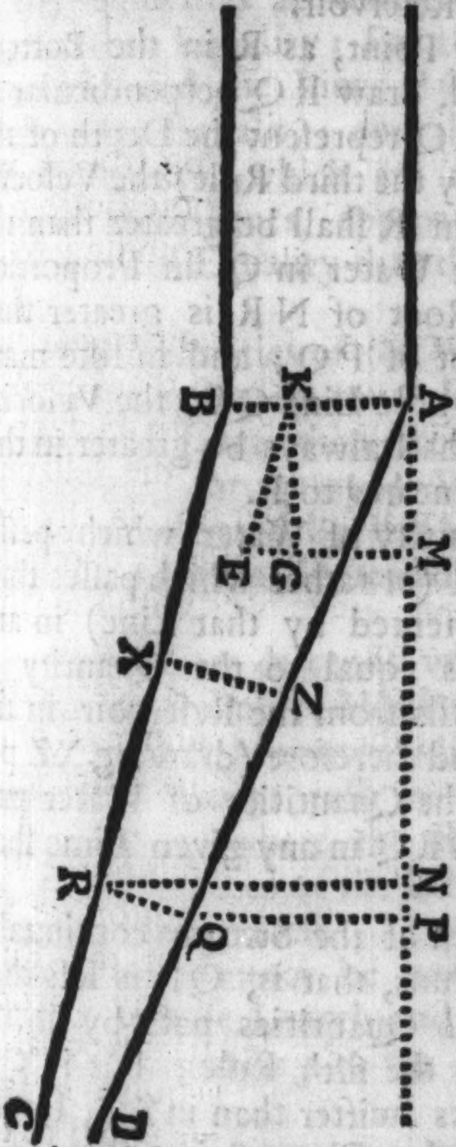
A Stream of Water deſcending from a Reſervoir, in a Channel whoſe Bottom is an inclined Plane, is called Running Water.

We here ſuppoſe the Reſervoir to be ſupplied as faſt as it is drained, ſo that the Water is always kept up to the ſame Height in the Reſervoir, and runs down the Channel in a conſtant permanent Stream, in any one Part of which the Water always continues at the ſame Height, and moves with the ſame Velocity. Wherefore,

1. Each Particle of Water is accelerated in deſcending, in the ſame manner as other heavy Bodies are accelerated in deſcending upon an inclined Plane.

2. Let A B repreſent the Depth of the Water in the Reſervoir, B C the Bottom of the Channel, and A D the Surface of the Running Water; the Velocity of any Particle E of the Running Water, ſhall be equal to the Velocity which it would acquire in falling perpendicularly thro' a Line equal to the preſent Depth of the Particle below the Plane of the Surface of the Reſervoir. Draw

EM parallel to BA, and EK parallel to BC, and KG perpendicular to ME. By the tenth Law of Oblique Deſcents, if a Body were to fall directly from A to K, and then deſcend obliquely from K to to E, it would acquire the ſame Velocity as if it fell directly from M to E. And by the ſixth Rule concerning Spouting Liquors, the Velocity with which the Water runs out of the Reſervoir at K, is equal to the Velocity it would acquire in falling from A to K. Therefore the Velocity of the Water at E ſhall be



equal to that which would be acquired in falling directly from M to E.

3. The Velocities of ſeveral Particles of Running Water are in ſubduplicate Proportion of their Depths from the Plane of the Surface of the Reſervoir.

4. From any Point, as R in the Bottom of the Channel, draw R Q perpendicular to B C, ſo ſhall R Q repreſent the Depth of the Water; and (by the third Rule) the Velocity of the Water in R ſhall be greater than the Velocity of the Water in Q, in Proportion as the Square Root of N R is greater than the Square Root of P Q; and in like manner thro' the whole Line Q R, the Velocity of the Water ſhall always be greater in that Point which is nearer to R.

5. The Quantity of Water which paſſes by the Line Q R (or rather which paſſes thro' the Plane repreſented by that Line) in any given Time, is equal to the Quantity of Water which falls from the Reſervoir in the ſame Time; and therefore (drawing X Z parallel to R Q) the Quantities of Water paſſing by X Z and R Q in any given Time ſhall be equal.

6. The Depth of the Stream continually decreaſes as it runs, that is, Q R is leſs than Z X. For equal Quantities paſs by in the ſame time, by the fifth Rule; but in Q R the Water paſſes ſwifter than in Z X, by the firſt Rule; and the Channel is ſuppoſed to be all the way of an equal Breadth. There-

fore the Depth QR muſt be leſs than the Depth XZ.

7. The farther the Stream runs, the nearer do the Velocities at different Depths approach to an Equality: For the Depth QR decreaſes, and the Lines PQ, NR, come nearer to an Equality; and the greateſt and leaſt Velocities, which are as the Square Roots of thoſe Lines, approach nearer to a Proportion of Equality than the Lines themſelves.

8. The Velocities of the Water at different Depths approach towards an Equality conſiderably faſter than according to the ſeventh Rule; for the upper Waters are continually accelerated by the lower, and the lower are continually retarded by the upper.

9. The Water deſcends with moſt Noiſe near the Beginning or Head of the Stream: For the loudeſt Murmurs will be produced where the Waters ruſh with the greateſt Force, that is, where the Relative Velocities, or Differences of the Deſcending Velocities, are the greateſt.

10. Water cannot be conveyed in any Channel, whoſe Length and perpendicular Altitude is according to the following Table.

Lengths.		*Perpendicular Altitudes anſwering to each Length.*	
623	Yards.	1	Inches.
882		2	
1060		3	
2160		12	
23	Miles.	357	Feet.

Theſe latter Numbers ſhew how much the Convex Surface of the Earth ſinks below the Level of its Tangent, at ſuch Diſtances from the Point of Contact as are expreſſed by the former Numbers. If a Channel therefore were made according to this Table, each End of it would be equally diſtant from the Center of the Earth.

11. In making Aqueducts, or conducting Rivers the common Way, is to make the Channel fall one Foot in 100 Yards.

12. If the Channel be of a ſufficient Length, and its Bottom rough and irregular, the Motion of the Stream ſhall become uniform in a very little time: For the Reſiſtance of ſuch a Channel to the Motion of the Stream will be very conſiderable, and will increaſe, as the Water accelerates, according to the Square of the Velocity, and will be gradually communicated from the Sides and Bottom to the very Middle of the Stream;

and ſo in a little time the Reſiſtance will become equal in effect to the Acceleration, and the Motion nearly uniform, as it commonly is in Rivers. Wherefore,

13. In Rivers, the Motion of the Water is floweſt at the Bottom and Sides of the Channel, becauſe there the Reſiſtance begins, and from thence is communicated to all other Parts.

14. In different Parts of the ſame River, the Uniform Velocity of the Stream is greateſt in that Part, where the Bottom of the Channel has the greateſt Inclination or Declivity.

15. In thoſe Parts of the River where the Velocity of the Stream is leaſt, the Depth of the Water is the greateſt.

Of the GRAVITATION *of* SOLIDS *and* FLUIDS *together.*

THE Specific Gravities of all Homogeneal Bodies are as the Weights of equal Bulks directly, or as the Bulks of equal Weights reciprocally.

If a Solid be immerſed in a Fluid, it loſes ſo much of its Weight as the Preſſure of the Fluid ſuſtains.

The Preſſure of the Fluid would ſuſtain the Weight of ſuch a Quantity of the Fluid as would fill the Space which the immerſed Solid takes up. For if there were ſuch a Quantity of the Fluid in the Place of the Solid, no one Part would move or preponderate, as has been already ſhewn.

If that Quantity of the Fluid, which is imagined to ſupply the Place of the Solid, were to harden and become ſolid itſelf, but to retain the ſame Denſity that it had before hardening; it would ſtill continue at Reſt, and be ſupported by the Preſſure: For the Quantity and Direction of the Preſſure between the remaining Fluid and the hardened Fluid, would in all Parts in all reſpects be the ſame that it was before.

Therefore every Solid immerſed in a Fluid loſes in Weight, ſo much as ſuch a Quantity of the Fluid weighs, as could fill its Place, and all equal Solids loſe the ſame Quantity of Weight; and every Solid immerſed in a Fluid, retains of its Weight, juſt ſo much as is the Exceſs of its own Specific Gravity, above the Specific Gravity of the Fluid.

So much Weight as the Immerſed Solid retains, is called its *Comparative* Gravity in that Fluid.

If the Specific Gravity of the Immerſed Solid be leſs than the Specific Gravity of the Fluid, then the Solid ſhall loſe more than its whole Weight; that is, the Exceſs of the

Fluid's Preſſure ſhall make it aſcend to the Surface, and ſwim there.

The Force which makes the Solid aſcend, may be called its *Comparative* Levity in the Fluid.

But if the Specific Gravity of the Immerſed Solid be greater than the Specific Gravity of the Fluid, then its Comparative Gravity ſhall cauſe it to deſcend and ſink to the Bottom.

The Comparative Gravity or Levity of an Immerſed Solid is the ſame at all Depths: For the Solid and Fluid being both ſuppoſed incompreſſible, the Difference of their Specific Gravities continues always the ſame.

Therefore in a Fluid void of Reſiſtance, all Immerſed Solids ſhall aſcend or deſcend with a Motion uniformly accelerated, like that of heavy Bodies deſcending *in Vacuo*, only making Allowance for the Difference of the Forces of Abſolute and Comparative Gravity.

But in Reſiſting Fluids, the Accelerations will continually decreaſe, till the Motion becomes nearly uniform, as has been already explained under the Head *Of Reſiſting Mediums*.

The true *Abſolute Gravity* of any thing, is only to be found by weighing it *in Vacuo*; tho' its Comparative Gravity in the Air is commonly taken for its Abſolute Gravity, becauſe the Difference between them is but ſmall.

A Solid ſpecifically lighter than a Fluid ſhall ſwim at the Top, Part of it being immerſed below, and Part of it emerging above the Surface.

The Immerſed Part of any Solid that ſwims, is equal in Magnitude to ſo much Fluid as weighs the ſame with the whole Solid. For if the whole Solid were taken away, and the Place of the immerſed Part ſupplied with an additional Quantity of Fluid, all Parts of the former Fluid would continue as they were.

Wherefore, a floating Solid increaſes the Preſſure upon the Bottom of the Veſſel, no otherwiſe than it would be increaſed by pouring in an additional Quantity of Fluid, whoſe Weight is equal to the whole Weight of the Solid, or whoſe Bulk is equal to the Bulk of the immerſed Part of the Solid. Wherefore,

If the Specific Gravities of the Solid and Fluid were equal, no Part of the Solid would emerge above the Surface of the Fluid; nor would the Solid have any Comparative Gravity or Levity, or be carried upward or downward in whatſoever Part of the Fluid it were placed.

And conſequently all Solids that float upon, or are ſuſpended in any Fluid, communicate their whole Gravity to the Fluid; nor is the Preſſure upon that Part of the Bottom which lies directly under the Solid, greater than upon any other Part.

The Magnitudes of the immerſed Parts of ſeveral Solids floating upon the ſame Fluid, are proportional to the Weights of the reſpective Solids. For the Magnitudes of ſuch Quantities of the Fluid as are of an equal Weight with the ſeveral Solids, are in that Proportion.

The Magnitude of the immerſed Part of the ſame Solid floating upon different Fluids, is reciprocally proportional to the Specific Gravity of each Fluid. For the Magnitudes of equal Weights of ſeveral Bodies, are reciprocally as the Specific Gravities of thoſe Bodies.

Thus the Hydrometer diſcovers the different Specific Gravities of all Fluids which are ſpecifically heavier than itſelf, by ſinking deepeſt into Fluids that have the leaſt Specific Gravity.

A Solid ſpecifically heavier than a Fluid, ſhall ſink to the Bottom, and there preſs with its whole Comparative Gravity.

So much Weight as the Solid loſes, (which is the Difference between its Abſolute and Comparative Gravity) is communicated to the Fluid: For the Preſſure of the Fluid upon the Bottom is increaſed, as much as its perpendicular Altitude is increaſed; and the perpendicular Altitude is increaſed, juſt as much as it would be increaſed by the Addition of ſo much Fluid as is equal in Bigneſs to the Bulk of the Solid.

Wherefore, in all Caſes, the Sum of the Weights of the Solid and Fluid is the ſame, whether they are weighed ſingly or together.

Whilſt the Solid is deſcending, the Weight of the Fluid that is under it increaſes continually, till the Reſiſtance becomes equal to the Acceleration: For the Preſſure of the Solid upon the Fluid increaſes, as the Reſiſtance of the Fluid increaſes, (Action and Re-action being always equal.) And therefore, when the Uniform Motion begins, the Preſſure of the lower Fluid is augmented by the whole Comparative Gravity of the Solid.

In like manner, the Comparative Levity of a Solid lighter than a Fluid, is communicated to the upper Fluid in Proportion to the Reſiſtance: So that when the Uniform Motion begins, the Preſſure of the upper Fluid will be leſſened by the whole Comparative Levity of the Solid.

If a Solid be immerſed in ſeveral Fluids, the Weights which it loſes in thoſe Fluids are as the Specific Gravities of the Fluids: For each Weight anſwers to an equal Bulk of each particular Fluid.

If ſeveral Solids which are ſpecifically heavier than any one Fluid be immerſed therein, the Weight which each Solid loſes, is to its entire Weight in Air, as the Specific Gravity of the Fluid to the Specific Gravity of the Solid. For the Weight loſt anſwers to ſuch a Bulk of the Fluid, as is equal in Magnitude to the Solid.

Having found the Proportion of the Specifick Gravity of one Fluid to the Specific Gravities of two Solids, we may eaſily find the Proportion of the Specific Gravities of thoſe Solids to each other. For as the Weight loſt by the firſt Solid is to its entire Weight, ſo is the Weight loſt by the ſecond Solid to a fourth Number; which, compared with the entire Weight of the ſecond Solid, expreſſes the Proportion of the Specific Gravity of the firſt Solid to the Specific Gravity of the ſecond. For the fourth Number expreſſes a certain Quantity in Weight of the firſt kind of Solid, which would loſe juſt as much as the ſecond loſes, and conſequently would be equal to its Magnitude.

The Specific Gravities of ſeveral Bodies are found to be as follows:

Fine Gold, - - -	19636
Gold of a Guinea, -	18888
Quickſilver, - - -	13593

Lead,	11345
Sterling Silver,	10535
Copper,	8843
Hammered Braſs,	8349
Caſt Braſs,	8100
Steel	7852
Iron,	7643
Tin,	7321
Glaſs,	2666
Pump-Water,	1000

The foregoing Numbers ſhew alſo how many Ounces Avoirdupois are contained in a Cubic Foot of each Solid or Fluid: And 192 Ounces Avoirdupois are equal in Weight to 175 Ounces Troy. And if any of the foregoing Numbers be divided by 1728, (the Cube of 12) the Quotient ſhall ſhew how many Ounces Avoirdupois are contained in one Cubic Inch.

The Specific Gravity of a Solid lighter than the Fluid in which it is immerſed, may alſo be found Hydroſtatically, by joining it to another Solid which is heavier than the Fluid; ſo that the whole Compound Solid may be alſo heavier. How this is to be done, will be beſt underſtood from an Example.

Let there be 34 Penny Weight of Lead, which being weighed in Water, loſes (ſuppoſe) three Penny Weight; and let 21 Penny ny Weight of Wax, which is lighter than Water, be faſten'd to the Lead, ſo ſhall the Weight of the Compound in Air be 55 Penny Weight; and let the Weight of the ſame Compound in Water loſe 25 Penny Weight, which ſhews how much a certain Quantity of Water weighs that is equal in Bulk to the Compound Solid: But a Quantity of Water, equal in Bulk to the Lead, weighs three Penny Weight. Therefore a Quantity of Water, equal in Bulk to the Wax, weighs (ſubſtracting 3 from 25) 22 Penny Weight.

OF
PNEUMATICS:

OR,

The Gravitation and Preſſure of ELASTICK *or* COMPRESSIBLE FLUIDS.

1. IT has been already ſhewn under the Head of *Repulſion*, that if the Particles of a Fluid repell each other with a Force reciprocally proportional to their Diſtances, ſuch a Fluid ſhall be Elaſtic, and capable of Compreſſion.

2. The Repulſive Force, as well as the Attractive, ſeems to ſtop at the firſt Particles it acts upon, never extending itſelf to other Particles which lie beyond the firſt in a right Line.

3. When the Particles of ſuch a Fluid are at Reſt, they are all at equal Diſtances from each other. For if the Diſtances were un-

equal, the Repelling Force would be greateſt where the Diſtance was leaſt; and conſequently the Particles would move that way where the Diſtance was greateſt.

4. Such a Fluid therefore would be homogeneal, and its Denſity or Specific Gravity would be proportional to the Number of Repelling Particles contained in any given Space.

5. The Denſity of ſuch a Fluid would always be proportional to its Compreſſion, which may be thus proved: The Number of equi-diſtant Particles in any given Line, is reciprocally as the Diſtance of the Particles: And the Number of equi-diſtant Particles in any given Surface, is reciprocally as the Square of the Diſtance of the Particles. For the Number of Particles in each Line is reciprocally as the Diſtance, and the Number of Lines in the Surface is reciprocally as the ſame Diſtance of the Particles: Therefore the Number of Particles in the given Surface, is reciprocally as the Square of the Diſtance. Again, the Number of equi-diſtant Particles in any given Solid, is reciprocally as the Cube of the Diſtance of the Particles: For the Number in each Surface is reciprocally as the Square of the Diſtance, and the Number of Surfaces in the Solid is reciprocally as the ſame Diſtance: Therefore the Number of Particles in the Solid is reciprocally

as

as the Cube of the Diſtance. Therefore alſo, the Denſity of ſuch a Fluid is reciprocally as the Cube of the Diſtance of the Particles. Now it is evident, that the Force of Compreſſion is in compound Proportion of the Number of Particles acting upon the Compreſſing Surface, and of the Repelling Force of a ſingle Particle; but the Number of Particles in the Compreſſing Surface is reciprocally as the Square of the Diſtance, and the Force of a ſingle Particle is reciprocally as the Diſtance: Therefore the Force of Compreſſion is reciprocally as the Cube of the Diſtance, that is, as the Denſity.

6. The Diſtance of the Particles of ſuch a Fluid, is proportional to the Cube Root of the Denſity, or Compreſſion, or Spring, which is always equal to the Compreſſion.

7. In all Homogeneal Bodies, the Denſities or Specific Gravities are reciprocally as the Bulks of equal Weights: Therefore the Magnitude of any given Quantity of ſuch a Fluid, is reciprocally proportional to the Denſity, Compreſſion, Spring, or Cube of the Diſtance of the Particles.

8. If a Fluid is compoſed of Repelling Particles, and if the Denſity of it be always proportional to its Compreſſion, then the Repelling Force in the Particles ſhall be reciprocally as their Diſtance. For ſince the Compreſſion is as the Denſity, that is, reci-

procally as the Cube of the Diſtance of the Particles; and ſince the Compreſſion is alſo in compound Proportion of the Square of the Diſtance reciprocally, and the Force of a ſingle Particle directly: Therefore the Force of a ſingle Particle is reciprocally as the Diſtance of the Particles.

9. Elaſtic Fluids conſiſt of Particles which don't touch each other: For if they ſhould touch or come within the Reach of Attraction, the Repelling Force, and conſequently the Elaſticity, muſt ceaſe.

Of AIR *and its* ELASTICITY.

THE Particles of Air give way to every ſmall Impreſſion, and move freely among one another; therefore Air is a Fluid.

Wherefore any Force that preſſes upon Air, preſſes in all manner of Directions at the ſame time.

Air becomes denſer when the Preſſure upon it is increaſed, and expands when the Preſſure is diminiſh'd, as is clear from Experiments.

The Force that compreſſes common Air, is the Weight of the Atmoſphere, and the Spring of the Air is equal to that Weight; for they always balance each other, and produce equal Effects.

We learn from Experiments, that the Denſity of the Air is proportional to the Force that compreſſes it; and conſequently (by the eighth Article of Elaſtic Fluids) the Air conſiſts of Particles repelling each other with a Force reciprocally proportional to their Diſtance.

And that the Repellent Force of each Particle of Air terminates on the neareſt Particles, is evident, becauſe if it did not, the Air contained in any Veſſel would be condenſed near the Sides of the Veſſel.

If the Diſtance of the Particles of Air in the Receiver of an Air-Pump be only ſeven times greater after exhauſting than it was before, the Mercury in the Gage will riſe within leſs than one Eighth of an Inch of its utmoſt Height, according to the preſent Weight of the Atmoſphere: For the Spring of the Air is as the Cube of the Diſtance of its Particles, by the ſixth Article of Elaſtic Fluids. Therefore (according to the preſent Suppoſition) the Spring before exhauſting, is to the Spring after exhauſting, as 1 to 343.

The Repulſive Vertue of the Particles of the Air is not to be overcome and changed into Attraction by any known Force whatever. Therefore by the ſixth Law of the Attraction of Coheſion, and the third Law of Repulſion, the Particles of Air are produced from Metals, or ſuch like hard and ponderous Subſtances.

Wherefore, when Water is changed into Vapour, by having its Parts ſeparated and put into a State of Repulſion, the Vapour is lighter than Air. This is the Reaſon why Watery Vapours float in the Air, and are raiſed up to conſiderable Height in the Atmoſphere, where its Weight, and conſequently its Preſſure and Denſity, is leſs than near the Surface of the Earth.

Hence it follows, that a moiſt Atmoſphere is heavier than a clear and dry Atmoſphere of the ſame Height.

The Preſſure of the Atmoſphere upon every ſquare Inch, (near the Surface of the Earth) is about 15 Pounds Avoirdupois. For the Preſſure of the Atmoſphere upon every ſquare Inch, is equal to the Preſſure of a Column of Mercury, whoſe Baſe is a ſquare Inch, and Altitude 30 Inches. Now from the Table of Specific Gravities it will be found, that a Cubic Inch of Mercury weighs ſomething more than 8 Ounces Avoirdupois: Therefore, 30 Cubic Inches ſhall weigh 15 Pounds.

If the Air was a compreſſed Fluid, the Height of the Atmoſphere would be 29040 Feet, or ſomething more than 5 Miles, reckoning 5280 Feet to a Mile: For the Preſſure of one Inch Altitude in Water is equivalent to the Preſſure of 850 Inches Altitude in Air; and the Preſſure of one Inch Altitude in Quickſilver, is equivalent to the Preſſure of $13\frac{2}{3}$ Inches Altitude of Water. Therefore the Preſſure of one Inch Altitude of Quickſilver, is equivalent to the Preſſure of 11616 Inches Altitude of Air; and the Preſſure of 30 Inches Altitude of Quickſilver, is equivalent to the Preſſure of 348480 Inches, that is, 29040 Feet Altitude of Air.

But the Atmoſphere muſt extend to a much greater Height than five Miles, as the Air is an Elaſtic Fluid, and expands itſelf at all Altitudes, in Proportion as the Preſſure of the incumbent Part of the Atmoſphere decreaſes.

Dr. *Halley* firſt found out and demonſtrated, that if Altitudes in the Atmoſphere are taken in Arithmetical Proportion increaſing, the Denſities of the Air, and conſequently the Heights of Mercury ſuſpended in a Tube, ſhall be in Geometrical Proportion decreaſing; and from thence he ſhewed how to determine the Height of the Mercury at any aſſigned Height in the Air, and *è contra* having the Height of the Mercury given to find the Height in the Air.

If the Logarithm of any Number leſs than 30 be ſubſtracted from the Logarithm of 30, and the Difference be multiplied by 58709, the Product ſhall give the Height in the Air expreſs'd in Feet, and the aſſumed Number leſs than 30 ſhall be the correſpondent Height of the Mercury expreſs'd in Inches. Hence the following Table is eaſily made.

Heights in the Air.	*Degrees of the Air's Expanſion.*
7	4
14	16
21	64
28	256
35	1024
42	4096

The Height of the Mercury anſwering to each of thoſe Heights in the Air, is found by dividing 30 Inches by the Degrees of the Air's Expanſion.

Wherefore, at the Height of 42 Miles in the Air, the Height of the Mercury would be little more than the hundredth Part of an Inch.

Of DAMPS *and* PESTILENCE.

ALL common Air is impregnated with a certain *Vivifying Spirit*, which is abſolutely neceſſary to the Preſervation and Continuance of the Animal Life.

Every time the Air paſſes out of the Lungs of an Animal, Part of the Vivifying Spirit is either deſtroy'd or left behind.

Theſe two Articles are evident, becauſe an Animal dies as well for want of *freſh* Air, as for want of Air.

It is found by Experience, that the Vivifying Spirit in a Gallon of common Air, is ſufficient for one Man about the Space of one Minute, and not much longer.

The Vivifying Spirit in Air is inflammable, or of a Nature proper to feed Fire, and capable of being burnt and conſumed thereby. This is evident,

1. Becauſe the Vivifying Spirit is actually deſtroy'd by making Air paſs through the Fire.

2. Becauſe when the Air has paſs'd thro' Fire, and loſt its Vivifying Spirit, it will deaden red hot Coals, and extinguiſh Flame.

3. Becauſe blowing of Fire makes it burn fiercer, except when the Blaſt is ſtrong enough to diſſipate the Particles of Fire immediately: For the Current of Air feeds the Fire with a continual Supply of inflammable Particles.

4. Becauſe Fire goes out of itſelf, if it be not fed with freſh Air.

5. Becauſe Cuſtom teaches, that the beſt way of making Fires is to contrive, not only that they may be ſupplied with freſh Air,

but that the Air, which paſſes thro' the Fire, may be thrown out thro' a Tube or Chimney, as being afterwards uſeleſs, or perhaps hurtful, both to the Burning of the Fire, and the Reſpiration of thoſe that are near the Fire.

Air that has loſt the Vivifying Spirit may be called a *Damp*, not becauſe it is filled with humid or moiſt Vapour, but becauſe it deadens Fire, extinguiſhes Flame, and deſtroys Life.

The Contrivance of warming a Room by ſupplying it with Air, heated by paſſing thro' the Fire, or a red hot Tube, ought to be rejected as dangerous, becauſe it fills the Room with an unwholeſome Damp, inſtead of freſh Air; and therefore, in ſmall and cloſe Rooms, it may prove mortal, unleſs there be a ſpeedy Admiſſion of healthful and ſpirituous Air.

The Elaſticity of a Damp is equal to the Elaſticity of common Air; for the Spring of the artificial Damp in the Receiver is equal to the Weight of the Atmoſphere.

Air may be changed into a Damp, not only by paſſing thro' the Fire, or thro' the Lungs of an Animal, but alſo by Corruption and Putrefaction of the Vivifying Spirit, as in the Hold of a Ship, or in Oil Ciſterns, after they have been emptied for ſome time.

The ſenſible Qualities of things putrefy'd, are different from the ſenſible Qualities which they had before Putrefaction, and affect the Bodies of Animals in a different manner.

Wherefore, during the Time that the Vivifying Spirit of Air is putrefying, it may reaſonably be conceived to undergo ſuch Changes as may quite alter its Nature, and endue it with malignant and poiſonous Qualities of divers Kinds and Degrees, till the Putrefaction is finiſh'd, and the Spirit entirely deſtroy'd and diſſipated, as if it had paſſed thro' the Fire.

If a conſiderable Part of the Vivifying Spirit of the Air in any Country begins to putrefy, the Inhabitants of that Country will be ſubject to an Epidemical Diſeaſe, which ſhall continue for a certain Period, till the Putrefaction is quite finiſh'd.

If as the Putrefying Spirit occaſions the Diſeaſe, ſo the Diſeas'd Body contributes towards putrefying the Spirit of the circumambient Air; then the Diſtemper ſhall not only be Epidemical, but alſo Peſtilential and Contagious.

Every Particle of Salt conſiſts of a dry, earthy, attracting Particle in the Center, encompaſſed with an acid, watry Fluid, which is retained and held faſt by the Central Attraction. For if it were not for the Central Attraction of each Particle, the watry Acid would conſtitute a Fluid; and if there were no watry Acid, the Salt would not be diſſolvible by the Moiſture of the Tongue, nor act upon the Taſte.

If the vivifying Spirit of the Air be a nitrous Salt, as is commonly believed, the manner of its Putrefaction is deſcribed by Sir *Iſaac Newton*, in the 31ſt Query, at the end of his Opticks.

'As Gravity makes the Sea flow round the 'denſer and weightier Parts of the Globe of the 'Earth, ſo the Attraction may make the watry 'Acid flow round the denſer and compacter 'Particles of Earth for compoſing the Particles 'of Salt. For otherwiſe the Acid would not 'do the Office of a Medium between the Earth 'and common Water, for making Salts diſ'ſolvible in the Water; nor would Salt of 'Tartar readily draw off the Acid from diſ'ſolved Metals, nor Metals the Acid from 'Mercury. Now as in the great Globe of 'the Earth and Sea, the denſeſt Bodies by 'their Gravity ſink down in Water, and al'ways endeavour to go towards the Center 'of the Globe; ſo in Particles of Salt, the 'denſeſt Matter may always endeavour to ap'proach the Center of the Particle: So that 'a Particle of Salt may be compared to a 'Chaos; being denſe, hard, dry, and earthy 'in the Center; and rare, ſoft, moiſt, and 'watry in the Circumference. And hence it ſeems to be that Salts are of a laſting Nature, being ſcarce deſtroy'd, unleſs by drawing away their watry Parts by Violence, or by letting them ſoak into the Pores of the Central Earth by a gentle Heat in Putrefaction, until the Earth be diſſolved by the Water, and ſeparated into ſmaller Particles, which by reaſon of their Smalneſs make the rotten Compound appear of a black Colour. Hence alſo it may be, that the Parts of Animals and Vegetables preſerve their ſeveral Forms, and aſſimilate their Nouriſhment; the ſoft and moiſt Nouriſhment eaſily changing its Texture by a gentle Heat and Motion, till it becomes like the denſe, hard, dry, and durable Earth in the Center of each Particle. But when the Nouriſhment grows unfit to be aſſimilated, or the Central Earth grows too feeble to aſſimilate it, the Motion ends in Confuſion, Putrefaction and Death.

Of HEAT, VAPOURS, *and* FLAME.

HEAT is communicated by thoſe Vibrations that Fire impreſſes upon the *Æther*, otherwiſe Heat could not be communicated through the Artificial *Vacuum*. The Elaſticity or Repulſive Vertue of the Particles of the Air is increaſed by Heat: For if a Bladder, which is about half filled with Air, be tied faſt about the Neck, and laid before the Fire, in a very little time it will be diſtended and burſt.

Fire communicates a Repelling Force to the Particles of all Bodies whatſoever, whether ſolid or fluid, and that Repelling Force increaſes as the Heat increaſes. Thus if a Flask be fill'd with Water only to the lower Part of the Neck, and then ſet upon the Fire, the Water, when it begins to grow warm, ſhall riſe into the Neck, and continue to aſcend higher and higher as the Heat augments. So alſo in ſolid Bodies, it is evident, that the Action of Heat tends to ſeparate their Parts; that is, it makes them fly from, or repell each other. For if a Bar of Iron be heated, it ſwells and increaſes its Dimenſions; but yet the Parts continue to ſtick together, ſo long as the Diſtance to which they are drawn by the Repulſion, is leſs than the Semidiameter of the Sphere of Attraction: When that Diſtance is almoſt equal to the Semidiameter, the Iron melts and becomes fluid; when the Diſtance is greater than the Semidiameter, the Particles are thrown off, and conſtitute an Elaſtic Fluid.

Heat is produced by violent Attrition, and alſo by the near approach of Bodies that are already hot.

For when the Parts of Bodies are agitated, either by Attrition or any neighbouring Heat, the *Æther* included in the Pores of thoſe Bodies is alſo agitated and repelled, and endeavours to expand, as in Electrical Attraction we find it does expand all round the Surface of the Electrical Body. And as the Agitation of the Parts of the heated Body increaſes, ſo the Elaſticity of the included *Æther* increaſes alſo, till by degrees the Pores are widened, the Attraction of Coheſion overcome, and the ſolid Parts ſeparated or thrown off into a State of mutual Repulſion.

Thoſe Bodies, whoſe Parts are ſeparated by a gentle Heat, are called *Volatile*; but ſuch Bodies whoſe Parts are not ſeparated without a ſtronger Heat, or perhaps not without Fermentation, are called *fixed* Bodies.

Thoſe Motions which are produced in Bodies by the Attractions or Repulſions of their conſtituent Particles, are called *Fermentation*, as all Chymical Fermentations ſeem to be of that Nature.

A fix'd Body can receive no greater Degree of Heat, than what is ſufficient to reduce it into the Form of a boiling Fluid. For when the *Æther*, meeting with no farther Reſiſtance, finds an eaſy Paſſage between the Particles, the Augmentation of the Elaſticity is then at an end. Therefore Water that has boil'd for a conſiderable time, is no hotter than when it firſt began to boil.

By how much greater the Force is, which is required to looſen and remove the Particles of which a Body is compoſed, by ſo much greater is the Degree of Heat which that Body is capable of receiving. Hence it is, that the Heat of melted Metal is much greater than of boiling Water; and that Water boils with leſs Heat *in Vacuo*, than when its Parts are preſſed together by the Weight of the incumbent Atmoſphere; and therefore, no doubt, the Heat of boiling Water is greater when the Air is clear, than when it is moiſt and rainy; and perhaps the Intenſeneſs of the Sun's Heat is owing to the vaſt Weight and Denſity of his Atmoſphere.

When the Agitation of the ſuperficial Parts of any fixed Body is great enough to emitt the *Æther* copiouſly in Right Lines, then that Body becomes bright or luminous.

If the Parts of a Body are agitated by Heat, to ſuch a Degree as to make them ſhine and become luminous, that Heat is called *Fire*, and the Body is ſaid to be *Red-hot.*

That groſs, terreſtrial, or ſulphureous Exhalation which aſcends from ſuch Bodies as are on Fire, is what we vulgarly call Smoak; and if the Smoak itſelf be on Fire, it becomes Flame; for Flame is nothing but red-hot, or ſhining Smoak.

The Heat of Flame may be made more intenſe, by blowing it out with a Tube into a pointed long Stream; for the Blaſt and the Air that encompaſſes the Stream, afford a very plentiful Supply of ſpirituous and inflammable Particles.

When Watry Particles are ſeparated and thrown off by Heat, they alſo acquire a Vertue of repelling each other, and conſtitute an Elaſtic Fluid, which is called Vapour.

Vapour has the greateſt Elaſticity, ſo long as it continues hot; for Cold quickly deſtroys the Elaſticity, and turns the Vapour into Water again.

The Strength of heated and confined Vapour is very well known by its raiſing Water, digeſting Bones, and burſting little Glaſs Spheres with a Report like that of a Piſtol. The ſtrongeſt Vapour is that which is produced from the Watry Acid of Nitre in the Firing of Gunpowder; for by means of the Charcoal and Sulphur, and Acidity of that Fluid of which the Nitre is compoſed, the rarifying Heat upon every Particle of the Vapour is both ſudden and violent.

Vapour aſcends ſo long as the Repelling Force is ſufficient to keep the Particles at ſuch a Diſtance, as makes the Specific Gravity of the Vapour leſs than the Specific Gravity of Air; but when Cold has brought the Particles cloſer together, it deſcends as it were by Diſtillation in Miſt and Rain.

The biggeſt Drops of Rain fall from the higheſt Clouds; for as the Vapour deſcends, it meets with other floating or aſcending Vapours in its Paſſage: Hence the Drops of Rain in Summer are commonly larger than in Winter.

The very odd *Phænomena* of Glaſs *Lachrymæ*, which are made by dropping melted Glaſs into Water, ſeem to be the natural and genuine Effects of Heat and Cold. For,

1. The melted Glaſs, as it falls through the Air, begins to cool, and conſequently to ſhrink; upon which the external Parts have an Opportunity of attracting each other, and forming a thin Surface or Skin of compact and hard Glaſs.

2. But the main Body of the *Lachryma*, before it reaches the Water, continues melted, and therefore the Diſtance of the Centers of the Particles is but little leſs than the Semidiameter of the Sphere of Attraction.

3. When the Heat is ſuddenly check'd by the Water, the Dimenſions of each Particle, and of its attracting Sphere, are immediately leſſened and contracted.

Wherefore, when the *Lachryma* is cold, all its internal Particles are in a State of Repulſion, being without the Reach of each others Attraction.

5. So long as the Elaſtical Preſſure continues equal in all Parts, the external Skin of ſolid Glaſs is ſufficient to confine it; but as ſoon as the Stem is broken off, and the repell'd Particles are at Liberty to begin to move, and in moving are accelerated by repeated Actions of the repelling Force, at laſt the whole Maſs ſuddenly burſts, and divides itſelf into a kind of coarſe tranſparent Sand.

If a *Lachryma* be made red-hot, and ſuffered to cool leiſurely, ſo that the Particles may attract each other as they ſubſide, it ſhall be entirely changed into true, perfect, vulgar Glaſs.

Of PNEUMATIC ENGINES.

ALL thoſe Inſtruments or Machines that work by means of an Elaſtic Fluid, may be called Pneumatic Engines.

One of the moſt ſimple is the Exhauſting Syringe, which is nothing but a common Syringe, with a Valve permitting the Air to enter through the Orifice into the Body or Barrel of the Syringe when the Piſton is drawn; but not to return back again through the Orifice when the Piſton deſcends.

The Condenſing Syringe is of the like Nature, only the Valve ſuffers the Air to paſs out of the Body of the Syringe when the Piſton deſcends; but not to enter again when the Piſton aſcends.

The Air Pump is in Effect nothing but two Exhauſting Syringes, communicating with each other, and acting alternately.

The Effect of the Cupping-Glaſs has ſometimes been aſcribed to the Spring of Air mixed with the Blood; but ought rather to be imputed to the Weight of the Atmoſphere preſſing upon thoſe Parts of the Blood-Veſſels which lie without the Glaſs. For,

1. It is plain, that the Weight of the Atmoſphere is ſufficient for that Purpoſe.

2. It is not certain, that there is any Air mixed with the Blood at all.

3. But, from ſeveral Trials, it ſeems to be pretty certain, that there is not in the Blood a ſufficient Quantity of Air to anſwer the Force with which the Fleſh is raiſed into the Glaſs in cupping.

The Diving-Bell is another Machine, whoſe Uſe depends upon the Elaſticity of the Air. This Engine is deſcribed by Dr. *Halley* in the following Terms:

'The Diving-Bell is moſt conveniently 'made in the Form of a *Truncate Cone*, the 'ſmaller Baſis being cloſed, and the larger 'open, and ought to be ſo poiſed with

‘ Lead, and ſo ſuſpended, that the Veſſel
‘ may ſink full of Air, with its greater or
‘ open Baſis downwards, and as near as
‘ may be in a Situation parallel to the Ho-
‘ rizon, ſo as to cloſe with the Surface of
‘ the Water all at once. Under this Cou-
‘ vercle, the Diver ſitting, ſinks down, to-
‘ gether with the included Air, to the Depth
‘ deſired; and if the Cavity of the Veſſel
‘ may contain a Tun of Water, a ſingle
‘ Man may remain therein at leaſt an Hour,
‘ without much Inconvenience, at five or ſix
‘ Fathoms deep.

The Preſſure upon the Surface of the Water is nothing elſe but the Weight of the Atmoſphere; at the Depth of ſix Fathoms, the Preſſure is equal to twice the Weight of the Atmoſphere; at the Depth of twelve Fathoms, the Preſſure is equal to thrice the Weight of the Atmoſphere; at the Depth of eighteen Fathoms, the Preſſure is equal to four times the Weight of the Atmoſphere; and ſo on continually.

Wherefore, at the Depth of ſix Fathoms, the Bell will be half full of Water, and half full of Air; at the Depth of twelve Fathoms, it will be two Thirds full of Water, and one Third full of Air; at the Depth of eighteen Fathoms, it will be three Fourths full of Water, and one Fourth full of Air; at the Depth of twenty four Fathoms, it will be four Fifths full of Water, and one Fifth full of Air, *&c.*

But Dr. *Halley* has entirely perfected the Art of living under Water, by ſhewing how to furniſh freſh Air at the Bottom of the Sea, in any ordinary Depths.

He gives the following Account of it in the *Philoſophical Tranſactions* for *Sept.* 1716.

'The Bell I made uſe of was of Wood, ' containing about ſixty Cubic Foot in its ' Concavity, and was of the Form of a *Truncate Cone*, whoſe Diameter at Top was ' three Foot, and at Bottom five. This I ' coated with Lead ſo heavy, that it would ' ſink empty, and I diſtributed the Weight ' ſo about its Bottom, that it would go ' down in a perpendicular Situation, and no ' other. In the Top, I fixed a ſtrong but ' clear Glaſs, as a Window to let in the ' Light from above; and likewiſe a Cock ' to let out the hot Air that had been breathed; and below, about a Yard under the ' Bell, I placed a *Stage* which hung by three ' Ropes, each of which was charged with ' about one hundred Weight, to keep it ' ſteddy. This Machine I ſuſpended from ' the Maſt of a Ship by a *Sprit*, which was ' ſufficiently ſecured by *Stays* to the Maſthead, and was directed by *Braces* to carry ' it over-board clear of the Ship-ſide, and ' to bring it again within-board as Occaſion ' required.

‘To ſupply Air to this Bell when under Water, I cauſed a couple of Barrels, of about thirty ſix Gallons each, to be caſed with Lead, ſo as to ſink empty; each having a Bung-hole in its loweſt Part to let in the Water, as the Air in them condenſed on their Deſcent; and to let it out again when they were drawn up full from below. And to a Hole in the uppermoſt Part of theſe Barrels, I fixed a Leathern Trunk or *Hoſe*, well liquored with Bees-Wax and Oil, and long enough to fall below the Bung-hole, being kept down by a Weight appended; ſo that the Air in the upper Part of the Barrels could not eſcape, unleſs the lower Ends of theſe *Hoſe* were firſt lifted up.

‘The Air-Barrels being thus prepared, I fitted them with Tackle proper to make them riſe and fall alternately, after the manner of two Buckets in a Well; which was done with ſo much eaſe, that two Men, with leſs than half their Strength, could perform all the Labour required; and in their Deſcent they were directed by Lines faſtned to the under Edge of the Bell, the which paſs'd through Rings placed on both ſides the Leathern *Hoſe* in each Barrel; ſo that ſliding down by thoſe Lines, they came readily to the Hand of a Man, who ſtood on the Stage on purpoſe

‘ to receive them, and to take up the Ends of the *Hoſe* into the *Bell.* Through theſe *Hoſe*, as ſoon as their Ends came above the Surface of the Water in the Barrels, all the Air that was included in the upper Parts of them was blown with great Force into the Bell, whilſt the Water entred at the Bung-holes below and filled them; and ſo ſoon as the Air of the one Barrel had been thus received; upon a Signal given, that was drawn up, and at the ſame time the other deſcended; and by an alternate Succeſſion furniſhed Air ſo quick, and in ſo great Plenty, that I myſelf have been one of five who have been together at the Bottom, in nine or ten Fathoms Water, for above an Hour and a half at a time, without any Sort of ill Conſequence; and I might have continued there as long as I pleaſed, for any thing that appeared to the contrary. Beſides, the whole Cavity of the Bell was kept entirely free from Water, ſo that I ſat on a Bench, which was diametrically placed near the Bottom, wholly dreſs'd with all my Cloaths on. I only obſerved, that it was neceſſary to be let down gradually at firſt, as about twelve Foot at a time; and then to ſtop and drive out the Water that entred, by receiving three or four Barrels of freſh Air, before I deſcended farther. But being ar-

‘ rived at the Depth deſigned, I then let out ‘ as much of the hot Air that had been ‘ breathed, as each Barrel would repleniſh ‘ with cool, by means of the Cock at the ‘ Top of the Bell; through whoſe Aperture, ‘ though very ſmall, the Air would ruſh ‘ with ſo much Violence, as to make the ‘ Surface of the Sea boil, and to cover it ‘ with a white Foam, notwithſtanding the ‘ great Weight of Water over us.

‘ Thus I found I could do any thing that ‘ was required to be done juſt under us; ‘ and that, by taking off the Stage, I could, ‘ for a Space as wide as the Circuit of the ‘ Bell, lay the Bottom of the Sea ſo far ‘ dry, as not to be over Shoes thereon. And ‘ by the Glaſs Window, ſo much Light was ‘ tranſmitted, that, when the Sea was clear, ‘ and eſpecially when the Sun ſhone, I could ‘ ſee perfectly well to write or read, much ‘ more to faſten or lay hold on any thing ‘ under us, that was to be taken up. And ‘ by the Return of the Air-Barrels, I often ‘ ſent up Orders, written with an Iron Pen ‘ on ſmall Plates of Lead, directing how to ‘ move us from Place to Place, as Occaſion ‘ required. At other times, when the Wa- ‘ ter was troubled and thick, it would be ‘ dark as Night below; but in ſuch Caſe, I ‘ have been able to keep a Candle burning ‘ in the Bell as long as I pleaſed, notwith-

‘ ſtanding the great Expence of Air requi-
‘ ſite to maintain Flame.

‘ This I take to be an Invention applica-
‘ ble to various Uſes; ſuch as *Fiſhing* for
‘ *Pearl*, Diving for Coral, Spunges, and
‘ the like, in far greater Depths than has
‘ hitherto been thought poſſible: Alſo for
‘ the fitting and plaining of the Foundati-
‘ ons of Moles, Bridges, *&c.* upon Rocky
‘ Bottoms; and for the cleaning and ſcrub-
‘ bing of Ships Bottoms, when foul, in calm
‘ Weather at Sea. But as I have no Expe-
‘ rience of theſe Matters, I leave them to
‘ thoſe that pleaſe to try. I ſhall only inti-
‘ mate, that by an Additional Contrivance,
‘ I have found it not impracticable for a
‘ Diver to go out of our Engine to a good
‘ Diſtance from it, the Air being conveyed
‘ to him with a continued Stream by ſmall
‘ flexible Pipes; which Pipes may ſerve as
‘ a Clew to direct him back again, when he
‘ would return to the Bell. But of this
‘ perhaps more hereafter.

Common Thermometers depend only upon the rarifying and condenſing of Fluids by Heat and Cold.

The Mercurial Barometer is nothing but a Column of Mercury ſuſpended by the Preſſure of the Atmoſphere in a Tube, the upper End of which is ſealed, the lower End open, and immerſed in Mercury.

Wherefore, it is evident that the Length of the Column of Mercury ſhall increaſe and decreaſe, as the Preſſure or Weight of the Atmoſphere increaſes and decreaſes.

The Weight of the Atmoſphere in any particular Part of the World may be actually diminiſh'd, when the Quantity of the incumbent Air is diminiſh'd, being drawn off by two contrary Winds blowing at the ſame time from the ſame Place, whereby the floating Vapours begin to fall, and in falling to form Drops of Rain.

Or the Weight of the Atmoſphere may be in Effect diminiſh'd, when its Preſſure is interrupted and broken by the Courſe of violent Winds paſſing over any Place. Hence the Barometer generally ſinks both in ſtormy Weather, and in calm rainy Weather.

The Weight of the Atmoſphere may be increaſed, when the Quantity of the incumbent Air is increaſed, being condenſed and accumulated by two contrary Winds blowing towards the ſame Place, whereby the floating Vapours are carried upwards, and ſuſpended in the Air at a great Diſtance from the Earth. Wherefore, in ſerene and calm Weather, the Mercury generally ſtands high.

In thoſe Parts of the World where the Winds are conſtant, as near the Equinoctial, there is but little Alteration in the Height of the Barometer: For that Alteration depends upon the different Preſſure of the Atmoſphere, and the Difference of that Preſſure depends upon the variable Winds whereby the Air is accumulated or carried away. Therefore the Height of the Barometer will vary moſt remarkably, in thoſe Regions that are ſubject to variable Winds.

A Gun is another Pneumatic Engine: For the ſwift Motion impreſſed upon the Bullet, is nothing but the Effect of the very great Elaſticity of nitrous Vapour or Flame.

When any Gun is diſcharged, the Quantity of Motion impreſſed upon the Piece, is equal to the Quantity of Motion impreſſed upon the Bullet; and in a contrary Direction, the Motion of the Piece is called *Recoiling*.

The Velocity with which the Piece recoils, is to the Velocity of the Bullet, as the Weight of the Bullet is to the Weight of the Piece. Therefore the only way to diminiſh the Velocity of recoiling, is to add more Metal, and increaſe the Fortification (or Weight) of the Piece.

The Force by which a Rocket mounts into the Air, is of the ſame Nature with the recoiling of a Gun; the Elaſticity of the Vapour being leſs where it expands and finds Vent, than where it is confined.

All manner of Inſtruments for conveying or augmenting of Sound, are alſo Pneumatical.

Sound is occaſion'd or excited by the ſtriking of condenſed Air upon the Drum of the Ear.

The Air is condenſed ſo as to produce Sound, either by the Colliſion of two Bodies, or the quick Vibrations of an elaſtic Body, or the ſudden and forcible Return of Air into a *Vacuum*.

As ſoon as the condenſing Force ceaſes, the condenſed Air begins to expand, and in expanding to condenſe the next adjacent Air; which afterwards expands alſo, and condenſes other neighbouring Air.

Thus the Condenſation of the Air is propagated ſucceſſively in a Sphere, whoſe Center is that Point where the Condenſation began.

As the condenſed Sphere ſpreads and increaſes in Diameter, ſo the Condenſation of the Air, and conſequently the Loudneſs of the Sound, decreaſes, till at laſt it becomes imperceptible.

As the Air condenſes and expands, the ſeveral Particles are made to oſcillate like a Pendulum, moving firſt forward, and then back again into their former Places, being driven back by the Condenſation of the next adjacent Air.

The Lines of Oſcillation decreaſe, as the Condenſation of the Air decreaſes; but the Time of Oſcillation continues the ſame, juſt as the Bigneſs of the Arch deſcribed makes no Difference in the Time of the Oſcillation of a Pendulum.

Wherefore the Motion of Sound is uniform, and keeps the ſame Velocity from the Beginning to the End of its Courſe.

In the ſame Conſtitution of the Air, all Sounds move with the ſame Velocity: For two Sounds of the ſame Tone differing in Loudneſs only, may be conſidered as one and the ſame Sound, taken at different Diſtances from the Center.

As to Sounds of a different Tone, it has been already proved, that they are Grave in Proportion to the Slowneſs, and Acute in Proportion to the Quickneſs, of the Original Impreſſion, whereby the Air is at firſt condenſed. Now it is evident, that the Diſtance to which the Air is condenſed by that Impreſſion, is proportional to the Duration of the Impreſſion, which is alſo equal to the Duration of the ſubſequent Oſcillations of each Particle of Air. Wherefore, by how much the Sound is graver, by ſo much is the Oſcillation ſlower, and by ſo much alſo is the Diſtance to which the Air is condenſed at every Oſcillation greater. Wherefore Grave and Acute Sounds move with the ſame Velocity.

If the Denſity of the Air increaſes in the ſame Proportion with its Elaſticity, the Velocity of Sound ſhall continue the ſame as before: For the Augmentation of the moving Force will be proportional to the Augmentation of the Quantity of Matter to be moved.

Sound has been obſerved to travel at the rate of about 1142 Feet in a Second of Time, or nearly 13 Miles in a Minute.

The Diſtance of 1142 Feet in a Second, is intended to expreſs the Velocity of Sound in Spring and Autumn. But in the Winter, when Cold increaſes the Denſity of the Air, and leſſens the Elaſticity, the Velocity is leſs; And in Summer, when Heat diminiſhes the Denſity, and increaſes the Elaſticity, the Velocity is greater than 1142 Feet in a Second.

In a Speaking-Trumpet, the Tube which hinders the Spreading of the Sphere, increaſes the Condenſation of the Air; the condenſed Air being thrown by the Oppoſition it meets with into the Axis of the Tube, from thence begins to dilate and ſpread itſelf as before, but with a greater Force; and in like manner, the Force receives a new Increaſe, every time the Dilation of the Sphere is obſtructed by the Reſiſtance of the Tube.

Hence it is, that the Augmentation of Sound paſſing thro' a Tube or Trumpet, is proportional to the Length of the Tube.

OF
OPTICS.

THAT Part of Natural Philoſophy which treats of Viſion and Viſible Objects, is called *Optics*.

All Viſion is performed by Rays of Light proceeding from the viſible Object, and entring the Pupil of the Eye.

Of the RAYS *of* LIGHT.

A Ray of Light is a Stream of *Æther* emitted from a Luminous Body, and proceeding in a Right Line, till it meets with ſome Obſtacle, or new Force, that ſtops it, or alters its Direction.

If Light conſiſted only in Preſſure or Motion propagated thro' a Fluid Medium, it would ſpread itſelf behind an opaque Object, and bend into the Shadow: For whatſoever Force preſſes upon any Point of a Fluid, is propagated from that Point, not only in the Line of the Direction of the Force, but alſo in all manner of Directions.

From Obſervations of the Eclipſes of the Secundary Planets revolving about *Jupiter*, Aſtronomers generally couclude, that Light ſpends about 7 or 8 Minutes of Time in paſſing from the Sun to our Earth. Sound moves about 13 Miles in one Minute of Time, that is, about 100 Miles in the ſame Space of Time that Light ſpends in moving from the Sun to the Earth, which is 70 Millions of Miles. Therefore Light moves 700000 times faſter than Sound.

The Sun's Rays being emitted into the ſtagnating elaſtic *Æther*, which is expanded thro' all the Heavens, will cauſe the Æthereal Particles to oſcillate, (as the Particles of Air oſcillate in the Propagation of Sound) and to form Waves, Pulſes, or Vibrations, whereby Heat will be convey'd and communicated from the Sun to us.

Every Viſible Point of any Object emitts Rays of Light into all Parts, from whence that Point is viſible.

Wherefore the Rays of Light proceeding from every Point of an Object, and paſſing thro' any ſmall Hole, ſhall form, on the other ſide of the Hole, an inverted Picture of that Object upon any opaque Surface on which the Rays fall.

The ſmaller the Hole is, the more diſtinct and perfect ſhall the inverted Picture be.

If the Hole be in the Middle, between the Object and the Surface upon which the Picture falls, the Picture ſhall be juſt as big as the Object; and in all Caſes, the Bigneſs of the Picture ſhall be to the Bigneſs of the Object, as the Diſtance of the Surface from the Hole is to the Diſtance of the Object from the Hole.

Wherefore, the Bigneſs of the Picture may be increaſed either by removing the Surface farther from the Hole, or bringing the Object nearer to the Hole.

Thus the Rays of Light which enter the Pupil of the Eye, delineate upon the Optic Nerve inverted Repreſentations of all Objects from whence thoſe Rays proceed.

But thoſe Repreſentations are render'd much more perfect by the Refraction of the ſeveral Humours of the Eye, thro' which the Rays paſs before they arrive at the Optic Nerve.

Of REFRACTION.

EVery thing that tranſmitts the Rays of Light is called a *Medium*, as Glaſs, Water, Air, *&c.*

In a ſimilar uniform Medium, the Rays of Light proceed in right Lines.

If a Ray paſſes from one Medium to another in a Line perpendicular to the common

Surface where thoſe Mediums join, it ſhall go on ſtill in the ſame right Line.

If a Ray falls obliquely upon the common Surface of two Mediums, it ſhall be bent in paſſing from one Medium to the other; and that Bending of the Ray is called *Refraction.*

As the Ray paſſes through the firſt Medium to the common Surface, it is called the *Incident* Ray; as the Ray paſſes from the common Surface through the ſecond Medium, it is called the *Refracted* Ray; and the Point where the *Incident* Ray falls upon the common Surface, is called the *Point of Incidence.*

A Line drawn through the Point of Incidence at right Angles to the common Surface, both above and below it, is called the *Perpendicular.*

The Angle made by the Perpendicular, and the Incident Ray, is called the *Angle of Incidence*; and the Angle made by the Perpendicular and the Refracted Ray, is called the *Angle of Refraction.*

The Sine of the Angle of Incidence, is called the *Sine of Incidence*; and the Sine of the Angle of Refraction, is called the *Sine of Refraction.*

In all Angles of Incidence, out of one given Medium into another given Medium, the Sine of Incidence is to the Sine of Refraction in a given Proportion.

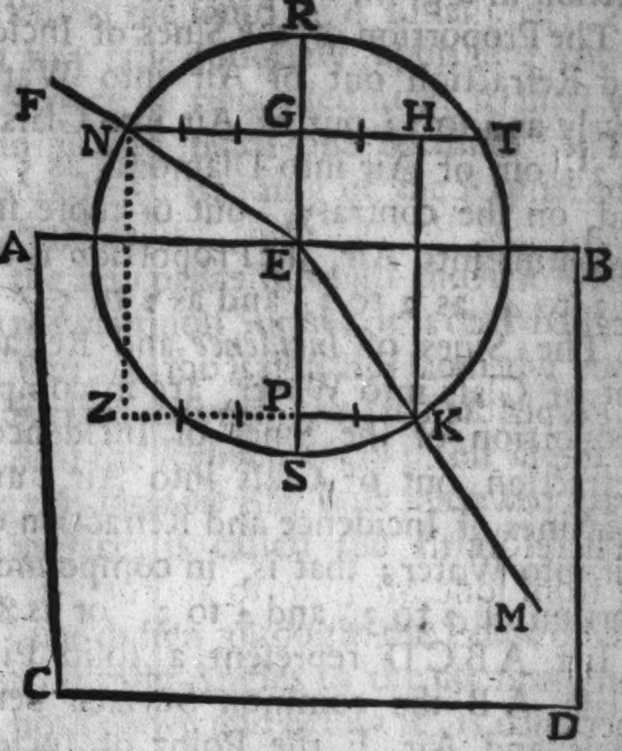
The Proportion of the Sines of Incidence and Refraction out of Air into Water, is nearly as 4 to 3; out of Air into Glaſs, as 3 to 2; out of Air into Diamond, as 5 to 2; and, on the contrary, out of thoſe ſeveral Mediums into Air, the Proportion is nearly as 3 to 4, as 2 to 3, and as 2 to 5.

The Sines of *Incidence* and Refraction, out of Glaſs into Water, are in compound Proportion of the Sines of Incidence and Refraction out of Glaſs into Air, and of the Sines of Incidence and Refraction out of Air into Water; that is, in compound Proportion of 2 to 3, and 4 to 3, or as 8 to 9.

Let A B C D repreſent a ſolid Piece of Glaſs, A B the common Surface between Glaſs and Air, E the Point of Incidence, F E the Incident Ray, E K the Refracted Ray, F E R the Angle of Incidence, N G the Sine of Incidence, S E K the Angle of Refraction, P K the Sine of Refraction, or K E the Incident Ray, E F the Refracted Ray, P K the Sine of Incidence, and N G the Sine of Refraction.

If F E be given, E K may be thus found. On the Center E, with any convenient Diſtance, deſcribe a Circle cutting F E in N; through the Point E draw R E S at right Angles to A B; and from the Point N, draw

N G T parallel to A B. Divide A G into three equal Parts, make G H equal to two



of thoſe Parts, and parallel to R S draw H K, cutting the Circle in K. Laſtly, draw E K M, which ſhall be the Refracted Ray; for P K is equal to G H; and therefore the Sine of Incidence N G is to the Sine of Refraction P K, as 3 to 2, which is the Proportion for Air and Glaſs.

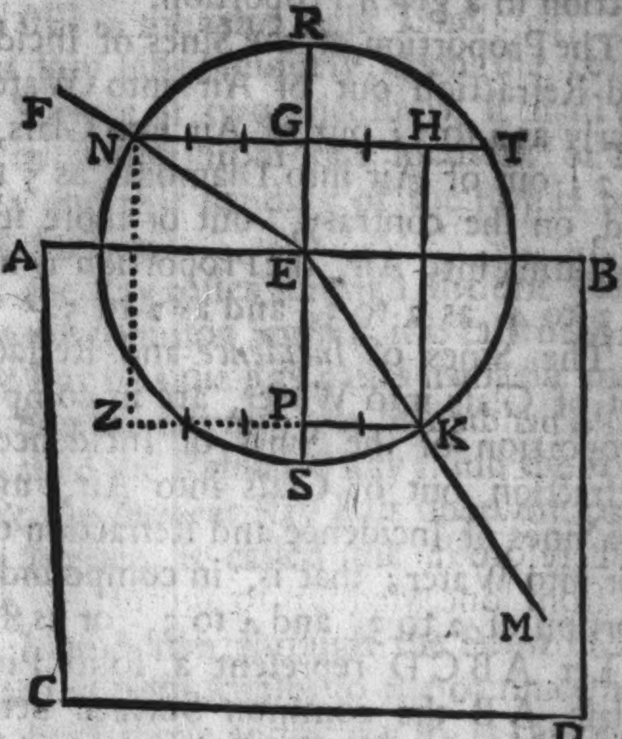
In the like manner, if the Incident Ray M E be given, the Refracted Ray E F out of Glaſs into Air may be thus found. On the Center E, deſcribe a Circle cutting M E in K, draw K P Z parallel to A B, divide P K into two equal Parts, make P Z equal to three ſuch Parts; from the Point Z, draw Z N, (parallel to R S) cutting the Circle in N. And laſtly, draw E N F the Refracted Ray.

The Refraction F E M, out of a rare Medium into a denſe, is called Refraction *towards the Perpendicular.* The Refraction M E F, out of a denſe Medium into a rare, is called Refraction *from the Perpendicular.*

But whether the Refraction be towards the Perpendicular, or from the Perpendicular, the Bending or Tendency of the Ray is always towards the denſer Medium.

Therefore the Refraction of a Ray in paſſing from one Medium to another, is produced by the Attraction of the denſer Medium; and this is farther confirmed from Experience; for we always find that the Refraction is greateſt, where the Difference of the Denſities of the Mediums is greateſt; except only, that all inflammable Mediums, as Oil, Spirits, *&c.* refract more in Proportion to their Denſity, than other Mediums, which is ſtill a farther Confirmation: For as Light, congregated by a Burning Glaſs, acts moſt upon ſulphurous and inflammable Mediums to turn them into Fire and Flame; ſo, ſince all Action is mutual, ſulphurous and inflammable Mediums ought to act moſt upon Light in bending and refracting its Rays.

N G T parallel to A B. Divide A G into three equal Parts, make G H equal to two



of thoſe Parts, and parallel to R S draw H K, cutting the Circle in K. Laſtly, draw E K M, which ſhall be the Refracted Ray; for P K is equal to G H; and therefore the Sine of Incidence N G is to the Sine of Refraction P K, as 3 to 2, which is the Proportion for Air and Glaſs.

In the like manner, if the Incident Ray M E be given, the Refracted Ray E F out of Glaſs into Air may be thus found. On the Center E, deſcribe a Circle cutting M E in K, draw K P Z parallel to A B, divide P K into two equal Parts, make P Z equal to three ſuch Parts; from the Point Z, draw Z N, (parallel to R S) cutting the Circle in N. And laſtly, draw E N F the Refracted Ray.

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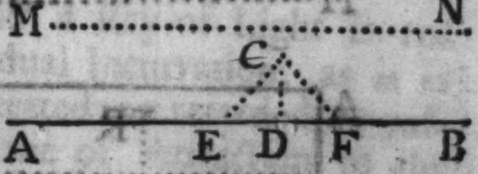
Rays. Wherefore the denſer of the two Mediums may be called the *Refracting* Medium.

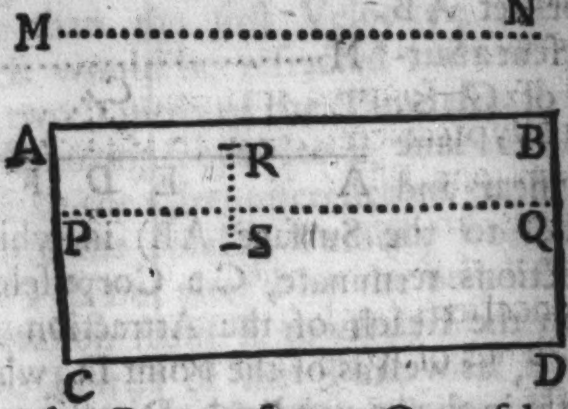
If the Ray FE, entring into the Body of the Glaſs, were accelerated at the Point E, by a Force acting in the Direction RES, and making the new Velocity one Third Part greater than the firſt Velocity; then the Ray FE would be refracted from E to K. For in two Thirds of the Time that the Ray ſpent in moving from N to E, it would move from E to the Circumference of the Circle; and ſince the parallel Velocity from N towards T is not alter'd by the perpendicular Acceleration from E towards S; therefore in two Thirds of the Time that the Ray ſpent in moving from N to E, it will move from E to ſome Point of the Line HK; conſequently, at the end of the two Thirds of that Space of Time, it will arrive at the Point K. So alſo when the Ray ME paſſes out of Glaſs into Air, if the ſame Force acts upon it at the Point E, and in the ſame Direction as before, the Ray will be retarded, and move from E to N, in half as much more Time as it ſpent in moving from K to E. In like manner, any other Degree of Refraction may be exhibited, if the Quantity of Attraction at the Point E be duly adjuſted, ſo as to accelerate the Ray at its Ingreſs, and retard it at its Egreſs, according to the Proportion of the Sine of Incidence to the Sine of Refraction.

A Ray of Light, as ſoon as it arrives within the Sphere of Attraction of the ſmall Parts of the Refracting Medium, will be accelerated in a Line of Direction perpendicular to the common Surface.



For let AB repreſent a Surface of Glaſs, MN a Plane (very near and parallel to the Surface AB) in which the Attractions terminate, C a Corpuſcle lying within the Reach of the Attraction of the Point E, as well as of the Point D, which attracts it in the perpendicular Direction; make DE equal to DF, and join CF. It is evident that the Corpuſcle C is attracted by the Point F as much as by the Point E; and it is alſo evident, that if the Force CE be reſolv'd into the Forces CD and DE; and if the Force CF be reſolv'd into the Forces CD and DF; the two equal and contrary Forces DE, DF, will deſtroy each other; and the two Forces that remain, ſhall act jointly with the Attraction of the Point D in a Direction perpendicular to the Surface of the Glaſs. Therefore the Corpuſcle C ſhall be accelerated only in the perpendicular Direction.

A Ray of Light, when it enters the Surface of the Refracting Medium, continues to be accelerated in the ſame Direction as before, till its Diſtance from the Surface within the Medium is equal to that Diſtance from the ſame Surface without the Medium, where the Attraction began.



For let R repreſent a Corpuſcle within the ſolid Glaſs, and PQ a Plane parallel to AB, and whoſe Diſtance from AB is equal to the Diſtance of MN from AB. Draw RS perpendicular to AB, and equal to the Diſtance of MN from AB. It is evident that the Corpuſcle R is accelerated in the Direction RS by the Attractions of all the Particles lying between R and S, and that the ſame Corpuſcle R is retarded in the Direction SR by the Attractions of all the Particles lying between the Point R and the Surface AB.

MN may by call'd the external, and PQ the internal Plane of Attraction.

When a Ray of Light arrives at the internal Plane of Attraction, it is accelerated no longer, becauſe the Attractions in contrary Directions deſtroy each others Effect.

In like manner, the Motion of a Ray of Light, going out of the attracted Body, is retarded during the Time of its Paſſage from the Internal Plane of Attraction to the External.

Wherefore, tho' a Ray of Light is refracted by a gradual Incurvation, as it is continually accelerated or retarded in paſſing from one Plane of Attraction to the other; yet, in Appearance, the Effect is the ſame, as if it were accelerated and refracted all at once in a ſingle Point; the Diſtance of the Planes of Attraction being ſo exceeding ſmall, that the Space in which the Refraction is performed, may very well be conſidered as a Point.

Of the REFRACTION *of* RAYS *by a Plane Surface.*

EVery Point from whence the Rays of Light flow, as from a Center, is called a *Radiant Point*, and the Rays are ſaid to *diverge* from that Point.

Of ſeveral Rays diverging from the ſame Point, thoſe are ſaid to be *moſt diverging*, or to *diverge faſteſt*, which contain the greateſt Angle.

If ſeveral Rays proceed, as if they flowed from a certain Point, which they do not in Reality flow from, that Point is called a *Vertual Radiant Point*; and in this Caſe alſo the Rays are ſaid to *diverge* from it.

Rays which tend towards any Point, are called *Converging Rays*; and that Point in which the Rays concur, is called the *Focus* of thoſe Rays; but that Point towards which they tend, and in which they do not concurr, is called their *Vertual Focus*.

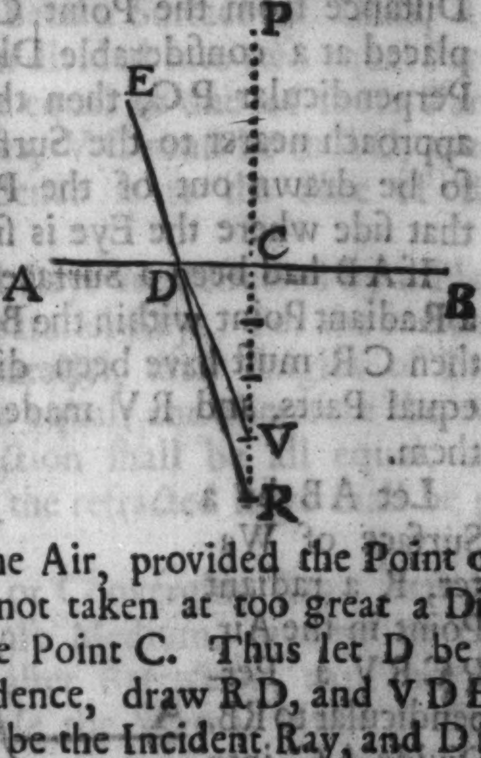
Thoſe Rays are ſaid to converge *moſt* or *faſteſt*, which, if continued, would make the greateſt Angle at the real or vertual Focus.

Thoſe Rays of Light which neither tend towards, nor proceed from any one Point, but always keep the ſame Diſtance, are called Parallel Rays. Parallel Rays may be conſidered as proceeding from a Point at an infinite Diſtance, and tending towards another Point at an infinite Diſtance alſo.

Thoſe Rays which proceed from any Point at an immenſe Diſtance, may be conſidered as Parallel Rays. Such are the Rays of Light flowing from any Point of the Body of the Sun; for the greater the Diſtance of the Point is from whence Rays flow, or towards which they tend, the nearer do thoſe Rays approach to a Parallel Direction.

Of the REFRACTION *of* RAYS *by a Plane Surface.*

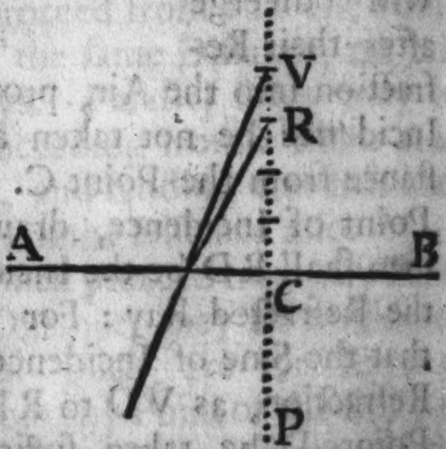
LET AB repreſent any Plane Surface of Water, R any radiant Point within the Water, RCP a Perpendicular to AB. Divide RC into 4 equal Parts, and towards C take RV equal to one of thoſe Parts; ſo ſhall V be the Vertual Radiant Point from which the Rays will diverge after their Refraction into the Air, provided the Point of Incidence be not taken at too great a Diſtance from the Point C. Thus let D be a Point of Incidence, draw RD, and VDE, then ſhall RD be the Incident Ray, and DE the Refracted Ray: For it is eaſily proved, that the Sine of Incidence is to the Sine of Refraction, as VD to RD; and that if the Point D be taken ſufficiently near to C, VD is to RD, as VC to RC; that is, as 3 to 4, which is the Proportion for Water and Air.



Wherefore to an Eye placed any where near the Perpendicular P C, the Point R ſhall appear to be in the vertual radiant Point V, becauſe the Rays fall upon the Eye in the ſame manner as if they had proceeded from V.

If the Point D be taken at a conſiderable Diſtance from the Point C, or the Eye be placed at a conſiderable Diſtance from the Perpendicular P C, then the Point V ſhall approach nearer to the Surface A B, and alſo be drawn out of the Perpendicular on that ſide where the Eye is ſituated.

If A B had been a Surface of Glaſs, and R a Radiant Point within the Body of the Glaſs, then C R muſt have been divided into three equal Parts, and R V made equal to one of them.



Let AB be a Surface of Water, R a radiant Point in the Air, P C R V a Perpendicular to RB. Divide A C into three equal Parts, and from C take RV equal to one of thoſe Parts; ſo ſhall V be the vertual radiant Point from whence the Rays will diverge after their Refraction into the Water, provided the Point of Incidence be taken near enough to the Point C; otherwiſe the Point V will remove farther from the Surface A B, and will alſo fall out of the Perpendicular on the contrary Side to that where the Eye is placed.

If A B had been a Surface of Glaſs, R C muſt have been divided into two equal Parts, and R V made equal to one of thoſe Parts. For in all Caſes, V C muſt be to R C, as the Sine of Incidence is to the Sine of Refraction.

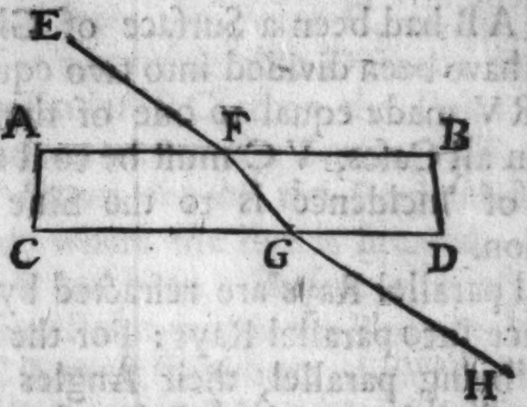
All parallel Rays are refracted by a Plane Surface into parallel Rays: For the incident Rays being parallel, their Angles of Incidence ſhall be equal, and therefore the Angles of Refraction ſhall be all equal, and conſequently the refracted Rays ſhall be parallel.

Diverging or Converging Rays, that paſs out of a denſe Medium, diverge or converge more after Refraction, than they did before, becauſe the Vertual Point or *Focus* comes nearer to the Surface of Refraction.

Diverging or Converging Rays, that paſs into a denſe Medium, converge or diverge leſs after Refraction, than they did before, becauſe the *Focus* or Vertual Point removes farther from the Refracting Surface.

A Ray of Light paſſing thro' a denſe Medium, terminated by two parallel Surfaces, ſhall go on after the two Refractions in the ſame Direction, tho' not preciſely in the ſame right Line.

Let ABCD be a ſolid Piece of Glaſs, with two parallel Surfaces AB, CD, and let



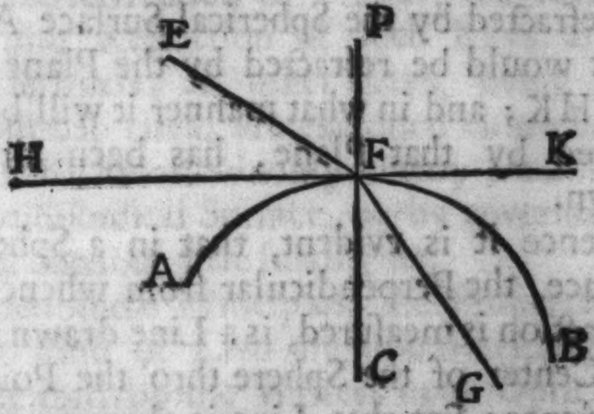
the incident Ray EF be refracted into FG, then ſhall FG be refracted by the ſecond Surface into GH parallel to EF, or in the ſame Direction with it; as is evident, becauſe the Angle of Refraction at the Point F is equal to the Angle of Incidence at the Point G; and therefore the Angle of Incidence at the Point F muſt be equal to the Angle of Refraction at the Point G.

Wherefore, Objects ſeen thro' a Refracting Medium, terminated with parallel Surfaces, will appear in the ſame Shape and Magnitude as when ſeen directly, and will alſo retain the ſame Situation with regard to each other; tho' with regard to other Objects which are ſeen directly, their Places will be ſomewhat alter'd; which Alteration however will be very inconſiderable, unleſs the Refracting Medium be pretty thick.

Wherefore, Rays of Light paſſing thro' a Medium, terminated by parallel Surfaces, may generally be conſidered as going on in one right Line, without any Refraction at all.

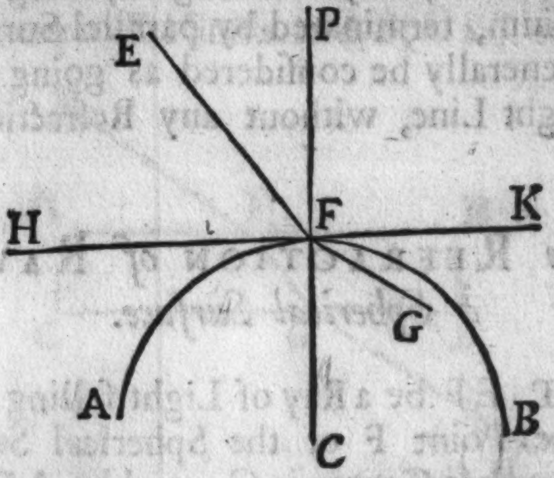
Of the REFRACTION *of* RAYS *by a Spherical Surface.*

LET EF be a Ray of Light falling upon the Point F of the Spherical Surface AFB, whoſe Center is C; and let AFB be



the Surface of a Medium denſer than Air in *Fig.* 1. and rarer than Air in *Fig.* 2. Join CF, and continue it towards P. Laſtly, thro' the Point F, at right Angles to CP, draw HFK, repreſenting a Plane, which touches the Spherical Surface in the Point F.

Since therefore the Space in which Refraction is perform'd, is to be conſidered as a Point, and ſince F is a Point in the Plane HK, as well as in the Spherical Surface AFB: Therefore the incident Ray EF ſhall be refracted by the Spherical Surface AFB, as it would be refracted by the Plane Surface HK; and in what manner it will be refracted by that Plane, has been already ſhewn.



Hence it is evident, that in a Spherical Surface, the Perpendicular from whence the Refraction is meaſured, is a Line drawn from the Center of the Sphere thro' the Point of Incidence: For that Line is always perpendicular to a Plane touching the Sphere in the Point of Incidence.

Of a LENS.

ANY Refracting Medium, terminated on one ſide by a Plane Surface, and on the other ſide by a ſmall Part of a Spherical Surface, or terminated on each ſide by a ſmall Part of a Spherical Surface, is called a *Lens.*

A *Lens* is either Plano-Convex, Double-Convex, Plano-Concave, Double-Concave, or a *Meniſcus*, which is convex on one ſide, and concave on the other.

A Line drawn thro' the Centers of both the Spherical Surfaces of any *Lens*, is called the *Axis of that Lens.*

In the Refraction of a *Lens*, we conſider only the Refraction of ſuch Rays as fall near the Axis; all other Rays, being unfit for Optical Uſes, are excluded either by taking into the *Lens* only a very ſmall Part of the Spherical Surface, or by covering the Edges even of that ſmall Part.

From theſe Principles, the Properties of every kind of *Lens* are Geometrically demonſtrated by the Writers upon Optics.

All the Rays proceeding from any radiant Point, whether at a finite or an infinite Diſtance, which fall upon any given *Lens*, are either made to diverge from ſome new Vertual radiant Point; or elſe collected into a

Real or Vertual *Focus*, at a finite or an infinite Diſtance.

When the incident Rays, being parallel to the Axis of a *Lens*, are collected by Refraction into one Point, that Point is called the *Principal Focus*.

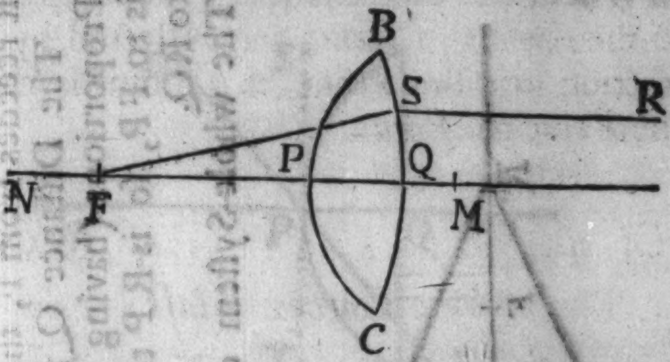
Of the REFRACTION *of* RAYS *by a Convex Glaſs.*

THE Principal *Focus* may be found experimentally, by holding the Glaſs directly againſt the Rays of the Sun, and obſerving the Center of that lucid Spot into which they are collected, ſo as to heat or burn moſt intenſly.

The Diſtance of the principal *Focus* from the Glaſs, may alſo be calculated from the following Proportion: As the Sum of the *Radii* of the two Convex Surfaces is to either *Radius* doubled, ſo is the other *Radius* to the Diſtance of the principal *Focus* from the Glaſs, provided the Thickneſs of the Glaſs be rejected as inconſiderable.

Let BPCQ be a Double-Convex Glaſs, MP the *Radius* of BPC, and NQ the *Radius* of BQC; and if the Thickneſs PQ be inconſiderable, then as the Sum of MP and NQ is to twice MP, ſo is NQ to

PF or QF, the Diſtance of the Glaſs from the Point F, into which all Rays, as RS, falling parallel to the Axis MN, ſhall be refracted.



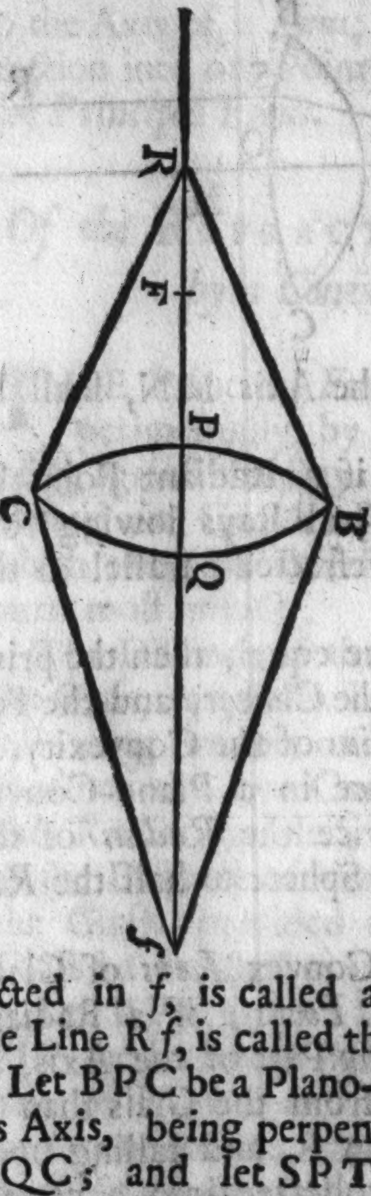
On the contrary, if a Radiant Point be placed in the Point F, all Rays flowing from it, as FS, ſhall be refracted parallel to the Axis.

If the two *Radii* are equal, then the principal *Focus* ſhall be the Center, and the Focal Diſtance the *Radius* of the Convexity.

The Focal Diſtance in a Plano-Convex Glaſs, is equal to twice the *Radius* of the Convexity, and in a Sphere to half the *Radius*.

Let BC be any Convex *Lens* of Glaſs, and F its principal *Focus*; if a Radiant Point be placed in any Part of the Axis, as at R, more remote from the Glaſs than F, all Rays flowing from R, and falling upon the *Lens*, ſhall be collected into a certain *Focus*, as *f*, on the other ſide.

The Diſtance QF is always greater than PF; and if the Point R approaches towards F, the Point f ſhall recede from Q; but if the Point R recedes from F, the Point f ſhall approach towards Q.

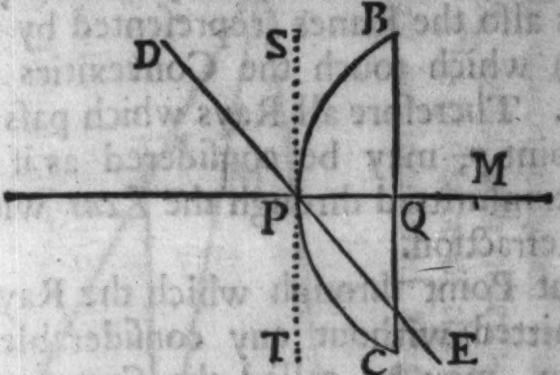


The Diſtance Qf may be found by the following Proportions (having firſt found FP as above.) As RF is to FP, ſo is RP to Qf; or as RF to RP, ſo is RP to RQ.

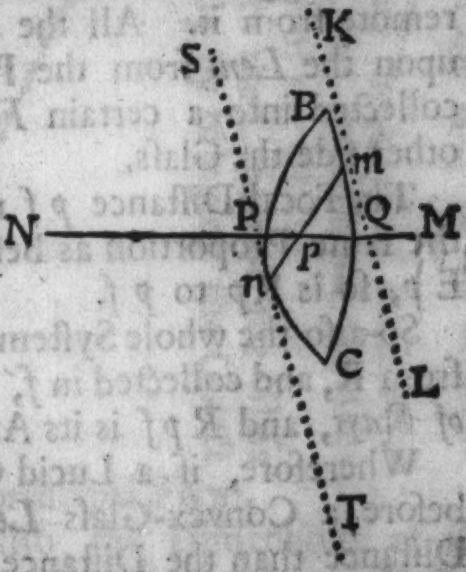
The whole Syſtem of Rays flowing from R, and collected in f, is called a *Pencil of Rays*, and the Line Rf, is called the *Axis of the Pencil*.

Let BPC be a Plano-Convex Glaſs, NPM its Axis, being perpendicular to the Plane BQC; and let SPT repreſent a Plane touching the Convexity in the Point P, and conſequently parallel to the Plane PQC.

Wherefore all Rays, as DPE, paſſing through the Point P, are to be conſidered as going on in one right Line without any Refraction at all; for all ſuch Rays are refracted at the Point P, in the ſame manner as they would be refracted by the parallel Surface TPS.



Let BC be a Double Convex, MP, NQ, the *Radii*, PQ the Thickneſs. Let PQ be divided, into two Parts, P*p* and *p* Q in Proportion to each other as MP to NQ; through the Point *p* let any Line be drawn, as *mpn*, terminated by the Convexities in *m* and *n*, through which Points let KL, ST, be drawn touching the



Arches B*n*C, B*m*Q. Now it is eaſy to demonſtrate from the Principles of Geometry, that the Lines KL, ST, ſhall be parallel, as alſo the Planes (repreſented by thoſe Lines) which touch the Convexities in *m* and *n*. Therefore all Rays which paſs thro' the Point *p*, may be conſidered as if they were tranſmitted through the *Lens* without any Refraction.

That Point through which the Rays are tranſmitted without any conſiderable Refraction, may be called the *Center of the Lens*.

Let BC be any Convex Glaſs, F its principal *Focus*, *p* its Center, and R a radiant Point lying without the Axis, but not too remote from it. All the Rays which fall upon the *Lens* from the Point R, ſhall be collected into a certain *Focus*, as *f* on the other ſide the Glaſs.

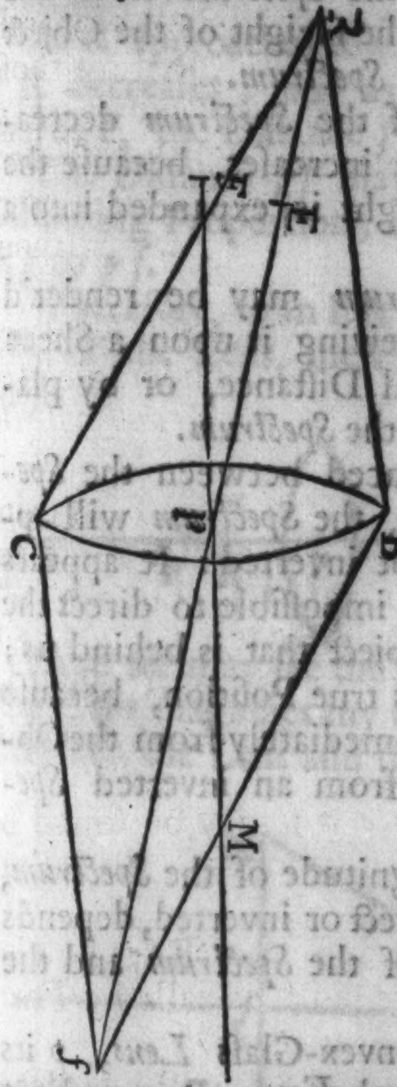
The Focal Diſtance *p f* may be found by the ſame Proportion as before. As RE to E*p*, ſo is R*p* to *p f*.

So alſo the whole Syſtem of Rays flowing from R, and collected in *f*, is called a *Pencil of Rays*, and R*pf* is its Axis.

Wherefore, if a Lucid Object be placed before a Convex-Glaſs *Lens*, at a greater Diſtance than the Diſtance of the Principal *Focus*, each Radiant Point of that Object will produce a ſeveral Pencil, having its proper *Focus* on the other ſide the Glaſs, whereby there will be formed an Image or *Spectrum* of the Object hanging in the Air, in an inverted Poſition.

The *Spectrum* is inverted, becauſe the Axes of thoſe Pencils which proceed from the Top and Bottom of the Object, croſs each other in the Center of the Glaſs.

The Diſtance of the *Spectrum* from the Center of the Glaſs may be increaſed at pleaſure, only by bringing the Object nearer to the principal *Focus*.



Wherefore alſo the Dimenſions of the *Spectrum* may be increaſed to any Magnitude, by increaſing its Diſtance from the Center of the Glaſs: For as the Diſtance of the Object from the Center of the Glaſs is to the Diſtance of the *Spectrum* from the ſame Center, ſo is the Height of the Object to the Height of the *Spectrum*.

The Brightneſs of the *Spectrum* decreaſes as its Magnitude increaſes, becauſe the ſame Quantity of Light is expanded into a larger Space.

The Aereal *Spectrum* may be render'd viſible, either by receiving it upon a Sheet of Paper at the Focal Diſtance, or by placing the Eye behind the *Spectrum*.

If the Eye be placed between the *Spectrum* and the Glaſs, the *Spectrum* will appear double and not inverted: It appears double, becauſe it is impoſſible to direct the Sight towards an Object that is behind us; and it appears in its true Poſition, becauſe the Rays proceed immediately from the Object itſelf, and not from an inverted *Spectrum*.

The apparent Magnitude of the *Spectrum*, whether it be ſeen erect or inverted, depends upon the Diſtance of the *Spectrum* and the Center of the Eye.

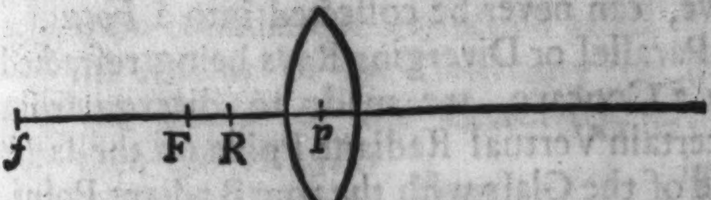
Let A B be a Convex-Glaſs *Lens*, *p* its Center, *f* its principal *Focus*, R a radiant Point placed between the Glaſs and the principal *Focus*. All the Rays flowing from the Point R ſhall be refracted by the *Lens* into Rays diverging from a certain

Vertual radiant Point, as *f*, on the ſame ſide of the Glaſs, with the Point R, but farther diſtant.

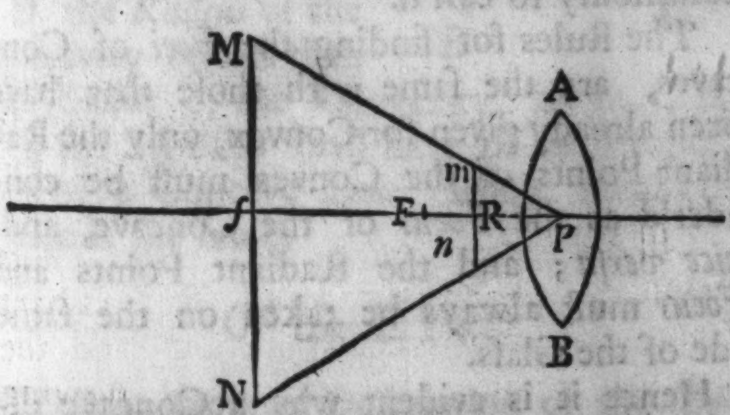
As R approaches towards *p*, the Diſtance *f* R decreaſes; but as R approaches towards F, the Diſtance *f* R increaſes.

The Diſtance *pf* may be found by the following Proportion; as RF to F*p*, ſo is R*p* to *pf*.

Wherefore, to an Eye placed on the other ſide of the Lens, the Point R ſhall appear in *f*.



Here we may ſee the Reaſon why a Convex *Lens* magnifies any Object that is placed between the Lens and the Principal *Focus*.



For let *m* R *n* be the Object, according to the foregoing Rules, the Point R ſhall appear in *ſ*, the Point *m* in M, and the Point *n* in N; therefore the Object *m* R *n*, ſhall appear to be M *ſ* N, both as to Place and Magnitude.

Of the REFRACTION *of* RAYS *paſſing thro' a Concave Glaſs.*

A Convex helps to unite, and a Concave to ſcatter the Rays: Therefore Parallel or Diverging Rays which fall upon a Concave, can never be collected into a *Focus*.

Parallel or Diverging Rays being refracted by a Concave, are made to diverge from a certain Vertual Radiant Point on the ſame ſide of the Glaſs with the true Radiant Point, but at a leſs Diſtance from the Glaſs.

This Vertual radiant Point is conſidered as the *Focus* of thoſe Glaſſes, and is alſo commonly ſo call'd.

The Rules for finding the *Foci* of Concaves, are the ſame with thoſe that have been already given for Convex, only the Radiant Points of the Convex muſt be conſider'd as the *Focus* of the Concave, and, *vice verſa*; and the Radiant Points and *Focus* muſt always be taken on the ſame ſide of the Glaſs.

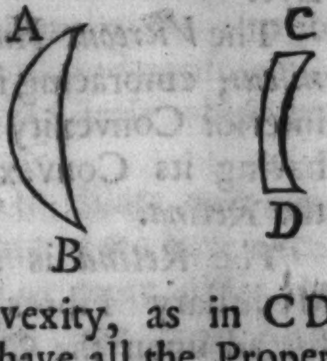
Hence it is evident why a Concave diminiſhes the Appearance of an Object; for in the laſt Figure, if we ſubſtitute a Concave in the room of AB, and conceive M*f*N to be an Object, the Point M ſhall appear in *m*, N in *n*, and *f* in R.

Of the MENISCUS.

HERE the Rule for the Principal *Focus* is, as the Difference of the *Radii* is to either of them doubled, ſo is the other *Radius* to the Focal Diſtance.

If the *Radii* are equal, the Surfaces will be parallel, and ſo there will no *Focus*, and indeed no conſiderable Refraction at all.

If the *Radius* of the Convexity be leſs than the *Radius* of the Concavity, as in AB, then the *Meniſcus* ſhall have all the Properties of a Convex *Lens* of the ſame Focal Diſtance.



If the *Radius* of the Concavity be leſs than the *Radius* of the Convexity, as in CD, then the *Meniſcus* ſhall have all the Properties of a Concave *Lens*, whoſe Focal Diſtance is the ſame.

Of the EYE.

FOR an accurate Deſcription of the Eye and all its Parts, I referr to the Treatiſes of Anatomy; it will be ſufficient for our purpoſe to take notice of ſuch Parts only, whoſe Uſe depends more immediately upon Optical Principles. Such are the three Humours, *Aqueous*, *Cryſtalline*, and *Vitreous*, the *Tunica Retina*, the *Ligamentum Ciliare*, and the *Iris*.

The *Cryſtalline Humour* is a double Convex, form'd from unequal *Radii*, the Convexity from the ſhorter *Radius* being placed inwards.

The *Aqueous Humour* is a *Meniſcus*, whoſe concave Surface embraces the exterior Convexity of the Chryſtalline, and whoſe Convex Surface, being cover'd with the *Tunica Cornea*, is the Outſide or viſible Part of the Eye.

The *Vitreous Humour* is likewiſe a *Meniſcus*, embracing in its Concave Surface the interior Convexity of the Cryſtalline, and having its Convex Surface encompaſs'd by the *Retina*.

The *Retina* is a fine Expanſion of the Medullary Fibres of the Optic Nerve, ſpread upon the Convex Surface of the Vitreous Humour, and covering the Bottom of the Cavity of the Eye.

The Humours ſerve to collect the Rays of the ſeveral Pencils into their proper *Foci*; and the *Retina* to receive the Image or *Spectrum* which thoſe Pencils form, and to convey the Senſation thro' the Optick Nerves to the common *Senſorium.*

The *Ligamentum Ciliare* is a Ring of Fibres, incloſing the Edges of the Cryſtalline, (like a circular Frame) and tending in right Lines towards its Center. When theſe Fibres contract, the Diſtance between the *Retina* and Cryſtalline is lengthen'd.

The Uſe of this Ligament is to adjuſt the Diſtance of the *Retina* from the Cryſtalline, according to the various Diſtances of the Object from the Eye.

The back Part of the Ligament is tinged with a deep Black, that ſo the Rays, which are reflected thither from the *Retina*, may be abſorb'd and ſtifled, and not reflected back again to the *Retina*, whereby the Images would be render'd indiſtinct and confuſed.

The *Iris* is that colour'd Circle which encompaſſes the *Pupilla.*

The Uſe of the *Iris* is to dilate and contract the *Pupilla*, according as we have occaſion to ſee more clearly or more diſtinctly. The wider the *Pupilla* is, the more Rays enter the Eye, and the Image is ſo much the more clear and vivid: The ſmaller the *Pupilla* is, the nearer are the Rays confined to the Axis of the Humours, and thereby the Images are render'd ſo much the more accurate, diſtinct and perfect.

But Viſion cannot be truly diſtinct in any Caſe, unleſs the *Foci* of the Pencils fall preciſely upon the *Retina.*

Some Eyes cannot ſee diſtinctly, becauſe the Refraction of the Humours is too ſtrong, ſo that the Rays are collected, and croſs each other before their Incidence upon the *Retina.* This Defect therefore may be remedied by a Concave Glaſs, which diſperſes the Rays, and removes the *Foci* to a greater Diſtance.

Some Eyes again cannot ſee diſtinctly, becauſe the Refraction of the Humours is too weak, ſo that the Rays fall upon the *Retina* before they are collected; this Inconvenience therefore may be help'd by a Convex Glaſs, which promotes the Union of the Rays, and brings the *Foci* nearer.

A good Eye collects the *Foci* upon the *Retina* with moſt Eaſe and Exactneſs, when the Object is at ſome conſiderable Diſtance, ſo that the diverging Rays fall almoſt parallel upon the *Pupilla.*

A ſingle Microſcope or Magnifying Glaſs is nothing but a Convex *Lens* of a very ſmall Focal Diſtance; the Object is placed near the principal *Focus*, in order to render Viſion diſtinct, by refracting all the diverging Rays into Rays parallel to the Axis of each

Pencil; and the Object is magnified by being ſeen at ſo ſmall a Diſtance.

The Object would appear of the ſame ſize without the Glaſs, if the Eye could ſee diſtinctly at the Focal Diſtance of the Microſcope. Wherefore the Microſcope does not magnify the Appearance of the Object, but only helps the Eye to ſee diſtinctly at ſo ſmall a Diſtance.

Of COMBINATIONS *of* GLASSES.

IN all Combinations, that Glaſs which is turn'd next the Object, is called the *Object* Glaſs; all the reſt are called *Eye* Glaſſes.

In all Optical Combinations, the Axis of all the Glaſſes are ſuppoſed to lie in one right Line.

The combining ſeveral Glaſſes into one Optical Inſtrument, is founded upon the five following Propoſitions; all which have already been explained and illuſtrated.

1. Parallel Rays incident on a Convex Glaſs, are collected by Refraction into the *Focus* of their reſpective Axis; and Incident Rays diverging from the *Focus*, are refracted parallel to the Axis of the Pencil.

2. Parallel Rays incident on a Concave Glaſs, are made by Refraction to diverge from the *Foci* of their ſeveral Pencils; and

Incident Rays converging to the *Foci*, are refracted parallel to the Axes of the Pencils.

3. The Croſſing of all the Axes of the Pencils, is in the Center of the Object Glaſs.

4. If an Object be placed at a proper Diſtance beyond the exterior *Focus* of the Object Glaſs, a *Spectrum* may be formed on the other ſide, at any given Diſtance from the Center of the Object Glaſs, and conſequently of any given Magnitude.

5. Viſion is render'd diſtinct, when Diverging Rays are thrown parallel upon the *Pupilla.*

Optical Inſtruments, conſiſting of a Combination of Glaſſes, are either Teleſcopes or Double Microſcopes. A Teleſcope is an Optical Inſtrument for diſcovering Objects at a great Diſtance, by exhibiting the Object magnified under diſtinct Viſion.

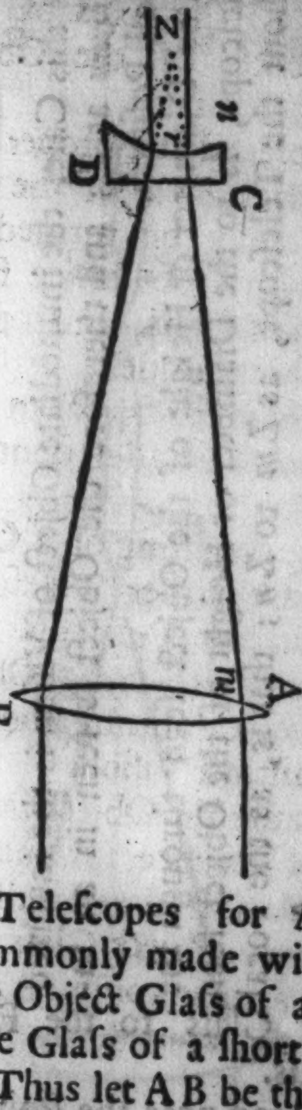
In Teleſcopes, becauſe the Object is ſuppoſed, to be at a great Diſtance, all incident Diverging Rays are conſidered as parallel.

Let AB be a Convex Object-Glaſs, CD a Concave Eye-Glaſs, Z their common *Focus*: This Combination is commonly called *Galileo*'s Teleſcope.

All Diverging Rays that fall upon A B, are to be conſider'd as Parallel; therefore (by *Prop.*

Prop. 1.) after Refraction, they ſhall converge towards Z, till they fall upon the Eye Glaſs; and (by *Prop.* 2.) after the ſecond Refraction, they ſhall fall parallel upon the *Pupilla*: Therefore (by the fifth *Prop.*) Viſion will be diſtinct.

The Diameter of an Object ſeen by this Teleſcope is to the Diameter of the ſame Object ſeen by the naked Eye, as Z*m* to Z*n*; that is, as the *Radius* or Focal Diſtance of the Object Glaſs is to the *Radius* or Focal Diſtance of the Eye Glaſs.

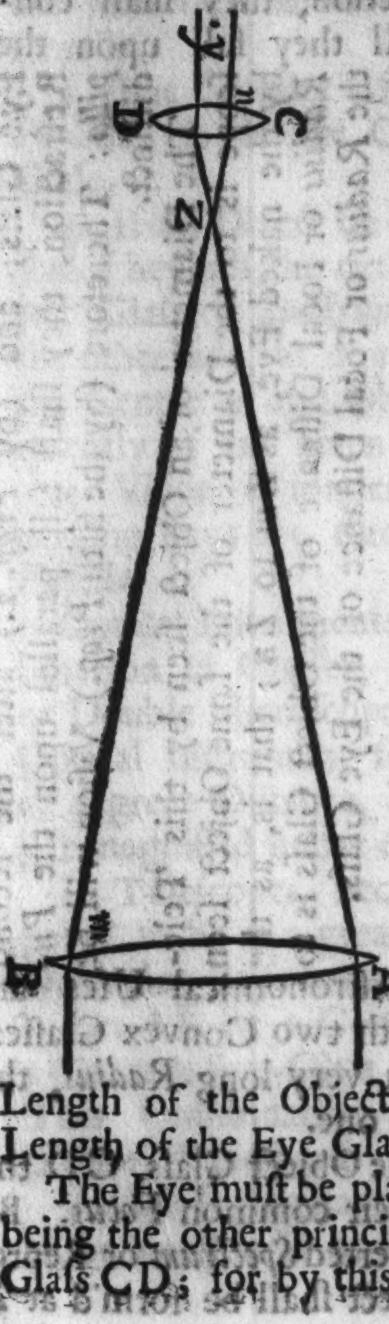


Teleſcopes for Aſtronomical Uſes are commonly made with two Convex Glaſſes, the Object Glaſs of a very long *Radius*, the Eye Glaſs of a ſhort one.

Thus let A B be the Object Glaſs, C D the Eye Glaſs, and Z their common *Focus*. By the *Lens* A B, an inverted *Spectrum* or Repreſentation of the Object ſhall be form'd at Z, from whence the Rays of each Point ſhall be thrown parallel upon the Eye, and Viſion rendered diſtinct.

In this Caſe, the immediate Object of Viſion is the inverted *Spectrum* at Z; and therefore the Object is ſeen in an inverted Poſition.

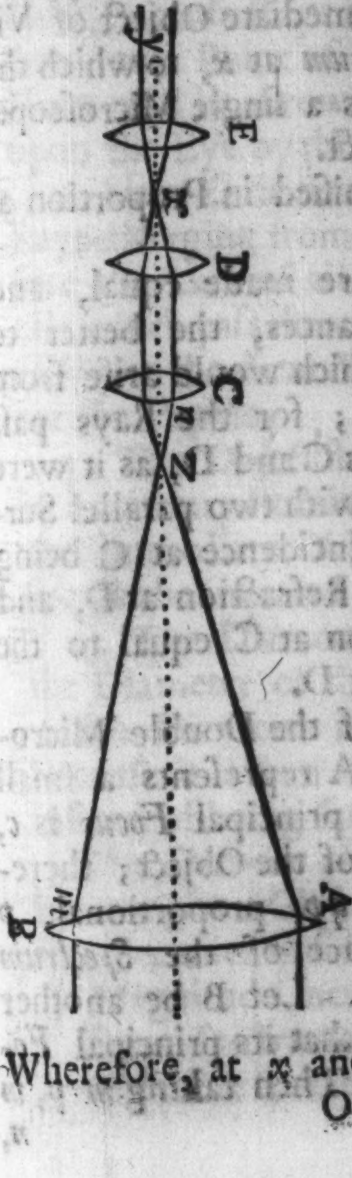
The Diameter or Height of the Object ſeen through the Teleſcope, is to the Diameter or Height of the Object ſeen without the Teleſcope, as Z*m* to Z*n*; that is, as the Focal Length of the Object Glaſs to the Focal Length of the Eye Glaſs.



The Eye muſt be placed near the Point *y*, being the other principal *Focus* of the Eye Glaſs CD; for by this means, all Rays proceeding from the *Spectrum*, parallel to the Axis of the Teleſcope, will enter the *Pupilla*, and become the Axis of ſo many ſeveral Pencils terminating upon the *Retina*.

The common Teleſcope for the Day, is made with three equal and equi-diſtant Eye-Glaſſes E, D, and C; the Point *x* is the common *Focus* of E and D, the Diſtance D C is made equal to the Diſtance E D, and Z is the common *Focus* of the Object Glaſs A B, and the third Eye Glaſs C; the Eye is placed at *y*, the other *Focus* of E.

An inverted *Spectrum* will be formed by the Object Glaſs at Z, from whence the Rays of each Point will be thrown parallel upon the *Lens* D, by the Refraction of the *Lens* C.



Wherefore, at *x* another *Spectrum* will be form'd equal in Magnitude to the *Spectrum* at Z, but in a contrary Poſition; that is, in the ſame Poſition with the Object. From the *Spectrum* at *x*, the diverging Rays will be thrown parallel upon the Eye by the *Lens.*

Thro' this Teleſcope the Object appears erect, becauſe the immediate Object of Viſion is the erect *Spectrum* at *x*, to which the *Lens* E ſerves only as a ſingle Microſcope, to render Viſion diſtinct.

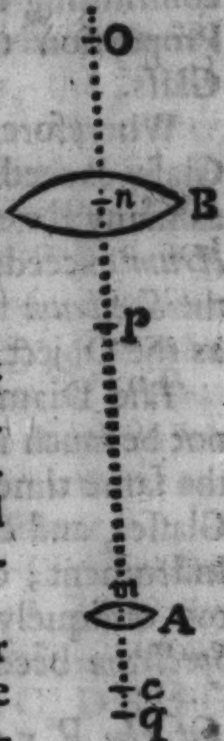
The Object is magnified in Proportion as Z*n* to Z*m*.

The Eye Glaſſes are made equal, and placed at equal Diſtances, the better to prevent the Colours which would ariſe from ſo many Refractions; for the Rays paſs through the two Glaſſes C and D, as it were through one Medium with two parallel Surfaces; the Angle of Incidence at C being equal to the Angle of Refraction at D, and the Angle of Refraction at C equal to the Angle of Incidence at D.

The Conſtruction of the Double Microſcope is as follows: A repreſents a ſmall Convex *Lens*, whoſe principal *Focus* is *c*, *q* repreſents the Place of the Object; therefore taking *q c*, *q m*, *q p*, proportional, *p* ſhall repreſent the Place of the *Spectrum* formed by the *Lens* A. Let B be another larger *Lens*, ſo placed that its principal *Focus* may fall upon *p*: Then taking *m p*, *m*

n,

n, *m*, O proportional, the Point O ſhall repreſent the Place of the Eye, looking through a ſmall Hole or Aperture. Hence it is evident,



1. That Viſion will be diſtinct, becauſe Rays diverging from any Point of the *Spectrum* will be thrown parallel upon the Eye by the *Lens* B.

2. Since O is the *Focus* of Rays diverging from *m*, therefore the Axes of all the Pencils which paſs through *m*, and fall upon the *Lens* B, ſhall enter the *Pupilla*.

3. The Object ſhall appear in a contrary Poſition, becauſe the immediate Object of Viſion is the inverted *Spectrum* at *p*.

4. The Diameter of the *Spectrum* is to the Diameter of the Object as *m q* to *c q*; which Diameter is alſo farther magnified, becauſe it is ſeen as from the Diſtance *n p*, inſtead of being ſeen from the Diſtance *o q*.

The *Spectrum* of any given Object, form'd by any given Glaſs or Combination of Glaſſes, becomes obſcure in ſuch Proportion as its Magnitude increaſes.

Equal *Spectrums* of the ſame Object, form'd by different Combinations, become obſcure in ſuch Proportion, as the Number of Rays conſtituting each Pencil decreaſes, that is, in Proportion to the Smalneſs of the Object Glaſs.

Wherefore, if the Diameter of the Object Glaſs exceeds the Diameter of the *Pupilla*, as many times as the Diameter of the *Spectrum* exceeds the Diameter of the Object; the *Spectrum* ſhall appear as clear and bright as the Object itſelf.

The Diameter of the Object Glaſs cannot be much increaſed, without increaſing at the ſame time the Focal Diſtances of all the Glaſſes, and conſequently the Length of the Inſtrument; otherwiſe the Rays would fall too obliquely upon the Eye Glaſs, and the *Spectrum* become confuſed and irregular.

Of the REFLECTION *of* RAYS.

1. THE Particles of every Medium act upon the Rays of Light as they paſs into it; therefore the Rays of Light act at the ſame time upon the Particles of the Medium.

2. The Particles of the Medium act, by bending and refracting the Rays; the Rays act, by exciting Tremors or Vibrations in the Medium, thereby agitating its ſolid Particles, and cauſing it to grow warm or hot.

3. Theſe Vibrations are propagated thro' the whole Medium by the *Æther* included

in its Pores, much after the Manner that Vibrations or Pulſes are propagated in the Air for cauſing Sound; only the *Æther* being much more Elaſtic than the Air, the Vibrations of it will be propagated much ſwifter, and indeed ſwifter than the Motion of the Rays themſelves, as appears from the Effects.

4. When theſe Vibrations or Pulſes overtake a Ray of Light, one Part of the Oſcillation retards the Motion of the Ray, the other conſpires with it and accelerates it. Thus, ſo long as a Ray continues to move in one and the ſame Medium, it is accelerated and retarded alternately at equal Diſtances.

Let A G repreſent a Ray of Light paſſing thro' any given Medium from A to G; then may A B, C D, E F, *&c.* repreſent the accelerated Parts of the Ray; B C, D E, F G, *&c.* the retarded Parts; *m*, *o*, *q*, &c. the Points where the Velocity is greateſt; *n*, *p*, *r*, &c. the Points where the Velocity is leaſt of all.

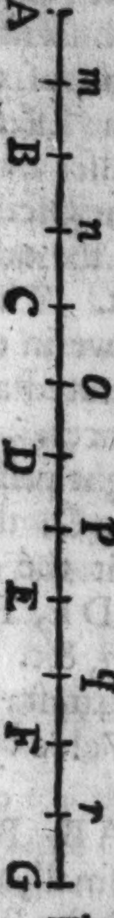
5. Note, that the Diſtances A B, B C, *&c.* muſt be conceived exceeding ſmall, that is, about $\frac{1}{89000}$th Part of an Inch in Rays which paſs perpendicularly out of any Medium into Air, and about $\frac{1}{137543}$th Part of an Inch in Rays that paſs perpendicularly out of any Medium into Glaſs, and about $\frac{1}{133500}$th Part of an Inch in Rays that paſs perpendicularly out of any Medium into

Water: And in general, (as Sir *Iſaac Newton* proves in his *Optics*) thoſe Diſtances are leſs in the denſer Medium, in Proportion of the Sine of Incidence to the Sine of Refraction.

6. Thoſe Diſtances are leaſt of all, when a Ray preſſes perpendicularly into any given Medium, and always increaſe as the Obliquity of the Ray increaſes.

7. The Diſtance A B, C D, E F, &c. may be called the *Intervals of Acceleration*; and the Diſtances B C, D E, F G, the *Intervals of Retardation.*

8. The ſmall Parts of all Bodies are tranſparent, and therefore all Reflection of Light is of the ſame Nature with that Reflection which is obſerved in the Surface of tranſparent Subſtances.



9. The Reflection of the Rays of Light may be conſidered under three different Circumſtances: For ſome Rays are reflected by the firſt or upper Surface of refracting Subſtances, and that at any Angle of Incidence, how ſmall ſoever: Some Rays alſo are reflected by the ſecond or lower Surface at any

Angle of Incidence, how ſmall ſoever; and in ſuch Angles of Incidence upon the ſecond Surface as are ſufficiently oblique, there will be a total Reflection of all the Rays.

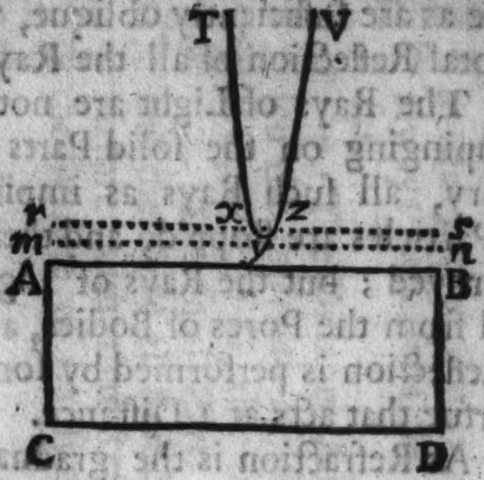
10. The Rays of Light are not reflected by impinging on the ſolid Parts; on the contrary, all ſuch Rays as impinge upon ſolid Particles are ſtopp'd, and their Motion is deſtroyed; but the Rays of Light are reflected from the Pores of Bodies, and therefore Reflection is performed by ſome Power or Vertue that acts at a Diſtance.

11. As Refraction is the gradual Inflection of a Ray by the attractive Power, ſo Reflection is the gradual Inflection of a Ray in ſome Caſes by the attractive Power, and in other Caſes by the repulſive Power.

12. Rays are reflected from the firſt Surface of a denſe tranſparent Subſtance, by the repulſive Power; for in that Caſe it is evident, that the Rays recede from the reflecting Body.

13. Let A B C D repreſent any tranſparent Body denſer than the ambient Medium, mn the exterior Surface of Attraction, rs the Surface of Repulſion, Tx any incident Ray entring within the Surface of Repulſion at x. If the Motion of the Ray be ſtrong enough, it ſhall break through the whole Repulſion, and enter the Surface of Attraction mn, and ſo be refracted into the tranſ-

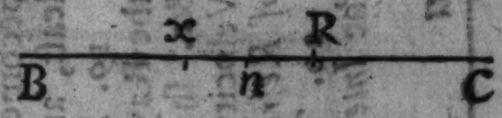
parent Body; but if the Repulſion be too ſtrong for the Motion of the Ray, then the Ray ſhall be gradually inflected from x, to y and z, and from thence emerge again in a contrary Direction zV, and ſo be reflected from the tranſparent Body before its Incidence thereon.



14. If we conceive the Curve xyz to be divided into two Parts xy, yz; at the Vertex y, thoſe Parts ſhall be equal and ſimilar to each other; for the Curve xy is produced by continual Retardations, and the Curve yz by continual Accelerations; which Retardations and Accelerations, in correſpondent Points of the Curves, are equal and in the ſame Direction.

15. Hence it follows, that the Angle of Incidence Txr, is equal to the Angle of Reflection Vzs; and becauſe of the Smal-

neſs of the Diſtance to which the Repulſion extends, the whole Curve xyz may be conſidered as a ſingle Point.



16. Let BC repreſent the Interval of Retardation in any Ray, n the Point where the Velocity is leaſt, x the Point at which the Incident Ray enters the Surface of Repulſion, and let n R be equal to xn: If the Repelling Force be but juſt ſtrong enough to reflect the Ray at the Point x, then all Rays whoſe incident Point falls between x and B, or R and C, ſhall be tranſmitted by Refraction; and all Rays whoſe incident Point falls between x and R, ſhall be turn'd back and reflected.

The Diſtance xR may be called the *Interval of Reflection*; and the Diſtance between any one Interval of Reflection and the next, may be call'd the *Interval of Refraction.*

17. Thoſe Bodies are found to have the ſtrongeſt Repulſion, which have the ſtrongeſt Attraction; and the ſtronger the Repulſion is, the greater is the Interval of Reflection; and the greater the Interval of Reflection is, the more Rays are reflected: Therefore thoſe Bodies reflect the moſt Rays, which have the greateſt refractive Power. Hence we learn,

on what Principle the Luſtre of a Diamond depends.

18. Let *a* be any Point in the Interval of Reflection, at which the Ray is reflected, if *ab*, *bc*, *cd*, *de*, &c. be taken ſeverally equal to the Interval of Acceleration or Retardation, the Points *a*, *b*, *c*, *d*, *e*, &c. ſhall become the Points in which the Velocity is leaſt, and are called the *Fits of Reflection.*

19. If the Point *a* be any Point in which the Ray is refracted, then the Points *a*, *b*, *c*, *d*, *e*, &c. ſhall become the Points in which the Velocity is greateſt, and are called the *Fits of Refraction.*

20. The Diſtances *ab*, *bc*, *cd*, &c. are called the *Intervals of the Fits.*

21. Let C D repreſent the ſecond or lower Surface of a tranſparent Body, T *n* an incident Ray not much inclined to the Perpendicular; it is evident that if *x* be a proper Point in the Interval of Retardation, the Ray ſhall be bent and reflected by the Attraction of the Body, much in the ſame manner as it was bent and reflected at the upper Surface by the Repulſion; only at the upper Surface, the Ray is turn'd back before it enters; but at the lower Surface, the Ray is drawn

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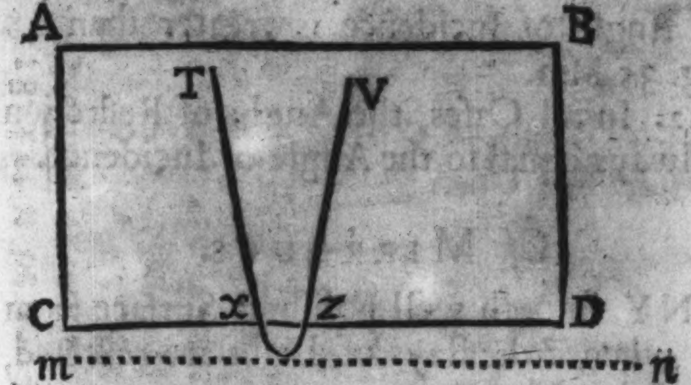
drawn in again after it has paſſed through the reflecting Surface.



21. The total Refraction of all Rays, (as well thoſe which at their Incidence are in a Fit of Refraction, as thoſe that are in a Fit of Reflection) happens at the ſecond Surface of any tranſparent Body, when the incident Ray is ſo oblique to the Surface upon which it falls, that the Sine of its Angle of Incidence is to the *Radius*, in a greater Proportion than that of the Sine of Incidence to the Sine of Refraction.

Thus if the Angle of Incidence of a Ray of Light paſſing out of Water into Air, be 40 Degrees 11 Minutes, the Angle of Refraction ſhall be 90 Degrees; that is, the Ray ſhall be refracted parallel to the refracting Surface; but if the Angle of Incidence be greater than 40 Deg. 11 Min. the Ray ſhall be drawn into the Water again and reflected.

In Glaſs, the total Reflection happens when the Angle of Incidence is greater than 48 Deg. 35 Min.

22. In all Caſes, the Angle of Reflection is always equal to the Angle of Incidence.

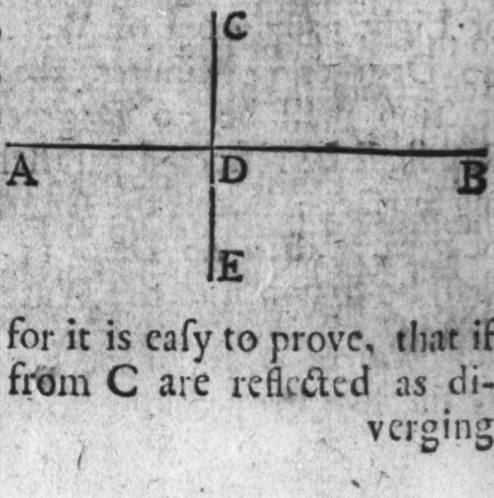
Of MIRROURS.

ANY ſmooth well poliſhed Surface from whence the Rays of Light are reflected, is called a *Mirrour*.

The Image of any viſible radiant Point is always to be found in ſome Point of the Perpendicular let fall from the radiant Point.

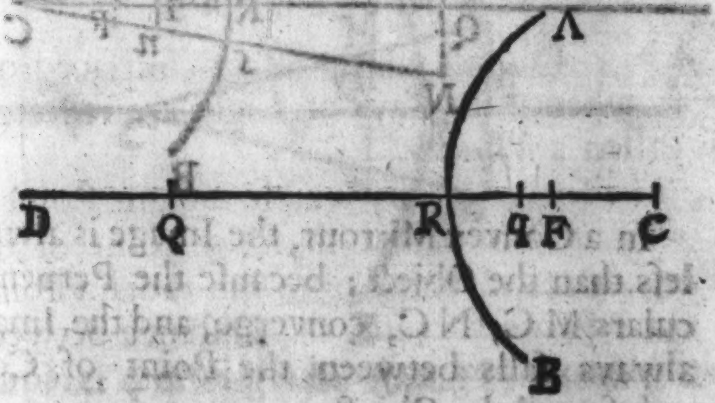
In a Plane Mirrour, the Diſtance between the Mirrour and any radiant Point, is equal to the Diſtance between the *Mirrour* and the Vertual *Focus* where the Image of that Point is found.

If A B be a Plane Mirrour, and C a Radiant Point; then letting fall C D E perpendicular to A B, and taking D E, equal to D C, the Point E ſhall be the Vertual *Focus*, or the Place of the Image of the Radiant Point C; for it is eaſy to prove, that if Rays diverging from C are reflected as di-



verging from E, all the Angles of Reflection ſhall be ſeverally equal to their Angles of Incidence.

Let A R B be a Convex Spherical Mirrour, C its Center, C R D its Axis, paſſing thro'



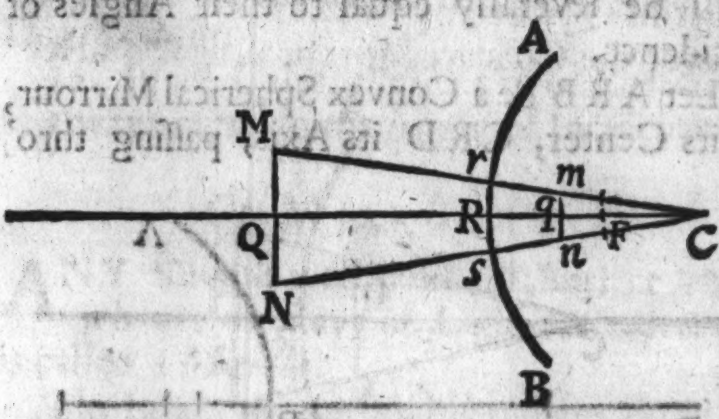
C the Center of the Sphere, and through R the middle of the Mirrour; and let Q be any Radiant Point in or near the Axis; then making R F equal to F C, and taking F *q* in ſuch Proportion to F R, as F R has to F Q, the Point *q* ſhall be the Vertual *Focus* to the Radiant Point Q, and the Angles of Reflection ſhall be equal to the Angles of Incidence.

If the Point Q be at an infinite Diſtance, the Point *q* ſhall fall upon F.

Let M Q N be any Object placed near the Axis, *q* the *Focus* of Q, found as above, *m* the *Focus* of M, and *n* the *Focus* of N, found by the like Proportion; ſo ſhall *mqn* be the

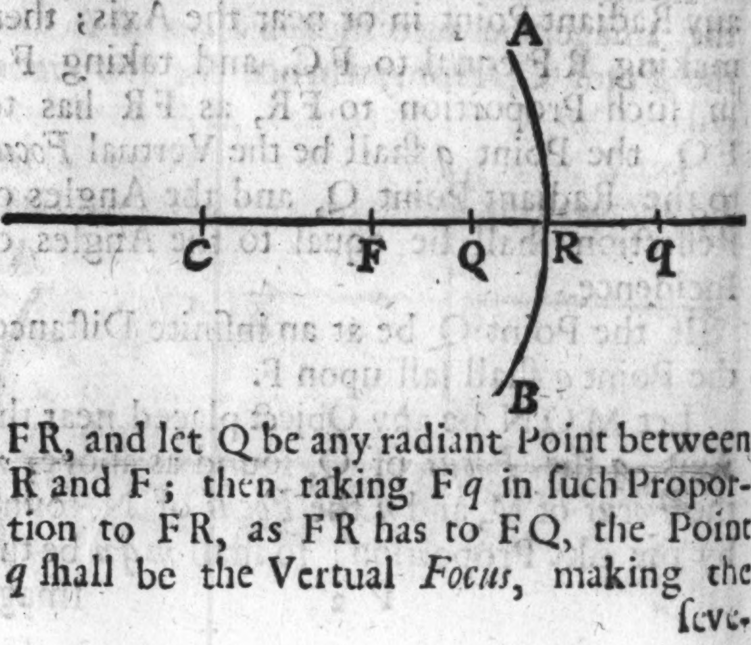
Image

the Image or Repreſentation of the Object MQN.



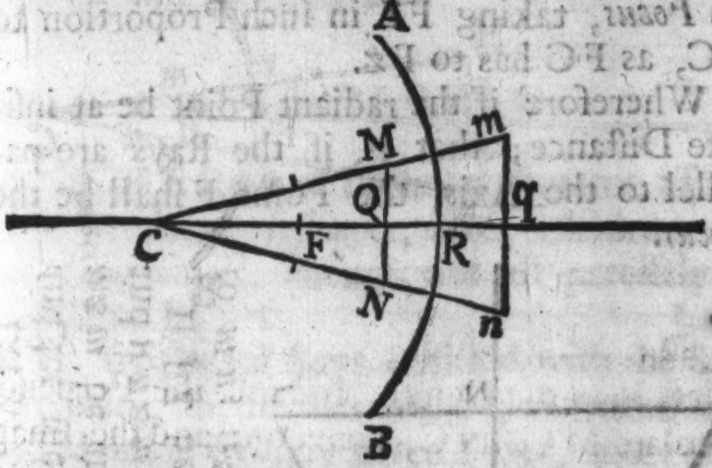
In a Convex Mirrour, the Image is always leſs than the Object; becauſe the Perpendiculars M C, N C, converge, and the Image always falls between the Point of Concourſe and the Object.

Let A R B be a Concave Mirrour, C its Center, C F R its Axis; make C F equal to



F R, and let Q be any radiant Point between R and F; then taking F q in ſuch Proportion to F R, as F R has to F Q, the Point q ſhall be the Vertual *Focus*, making the ſeveral Angles of Reflection equal to their reſpective Angles of Incidence.

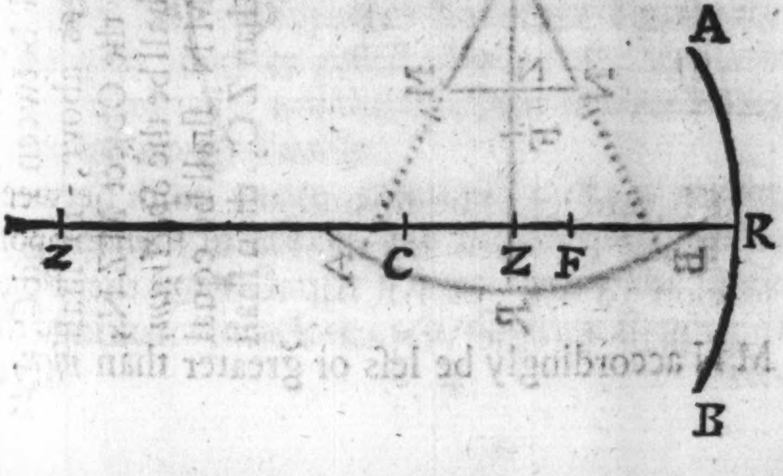
Let M Q N be any Object placed near the Axis of the Concave Mirrour A R B, and let



the *Foci q m* and *n* be found as above; ſo ſhall *m q n* be the Image or Repreſentation of the Object M Q N.

In this Caſe, the Object will be leſs than the Image, becauſe the Object is nearer to the Point C, from whence the Perpendiculars C *m*, C *n*, diverge.

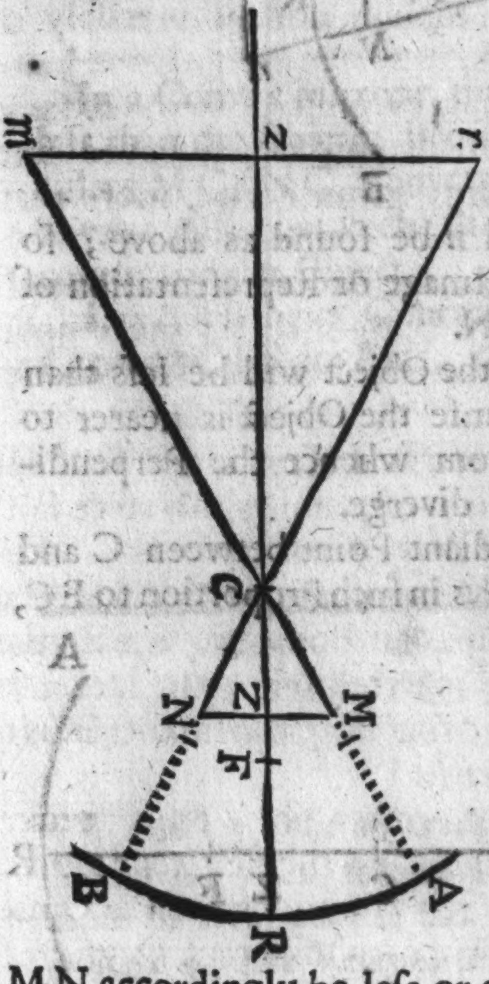
Let Z be a radiant Point between C and F; then taking F z in ſuch Proportion to F C,



as FC has to FZ, the Point *z* ſhall be the *Focus* to which the Rays ſhall converge after Reflection.

And if *z* be the radiant Point, Z ſhall be its *Focus*, taking FZ in ſuch Proportion to FC, as FC has to F*z*.

Wherefore if the radiant Point be at infinite Diſtance; that is, if the Rays are parallel to the Axis, the Point F ſhall be the *Focus*.



Let MZN be an Object placed between F and C, and let the *Foci* *mzn* be found as above, ſo ſhall *nzm* be an Image or *Spectrum* of the Object MZN; and if *nzm* be the Object, MZN ſhall be the *Spectrum*.

If FZ be equal to ZC, then MN ſhall be equal to *mn*; if FZ be leſs or greater than ZC, then ſhall MN accordingly be leſs or greater than *mn*.

It is evident, that the *Spectrum* muſt be inverted, becauſe the Point C, where the Perpendiculars interſect, falls between the Object and the *Spectrum.*

Of COLOURS.

1. THE Rays of Light are Streams of Æthereal *Effluvia*, all of which are exceeding ſmall, though not all preciſely of the ſame Bigneſs.

2. Of ſeveral Rays emitted with the ſame Velocity, the ſmaller will be influenced and acted upon by any given Force, more than the larger.

3. Wherefore, the Attraction and Repulſion of the ſame Body ſhall act more upon ſome Rays, than upon others, even in like Circumſtances.

4. Of two refracted Rays, the ſmalleſt ſhall be refracted moſt, and is therefore ſaid to be *more refrangible* than the other.

5. Of two Rays whoſe Angles of Incidence upon any tranſparent Body are equal, the ſmaller may be reflected when the larger is tranſmitted; and therefore the ſmaller is ſaid to be *more reflexible.*

6. The more refrangible Rays excite ſmaller Vibrations, and the leſs refrangible Rays excite larger Vibrations in the Optic Nerve; wherefore each different Degree of Re-

Refrangibility occaſions a different Senſation.

7. Rays endued with the ſame Degree of Refrangibility, are called *Homogeneal*; and Rays endued with different Degrees of Refrangibility, are called *Heterogeneal*.

8. The Light of the Sun conſiſts of Heterogeneal Rays, amongſt which all thoſe that are Homogeneal exhibit the ſame Colour, and all thoſe that exhibit different Colours are Heterogeneal; and each Ray exhibits its proper Colour anſwering to its Degree of Refrangibility, which Colour cannot be changed by any Refractions or Reflections whatſoever.

9. The ſimple primary Colours are ſeven; Red, Orange, Yellow, Green, Blue, Indico, Violet; the greateſt Degree of Refrangibility belongs to the deep Violet, the leaſt Degree of Refrangibility belongs to the deep Red, and intermediate Degrees of Refrangibility to the intermediate Colours.

10. A proper Mixture of all the ſeven primary Colours makes Whiteneſs. A Mixture of ſome of the primary Colours produces a compound Colour, which in ſome Caſes is like, and in other Caſes unlike to the Colours of Homogeneal Light.

11. All compound Colours are mutable, and may be again reſolved by Refraction into the primary Colours of which they were compounded.

12. All Colours in the Univerſe, which are made by Light, are either the primary Colours, or Colours compounded of the Primary; for Reflection or Refraction cannot alter the Colour of any one Ray.

13. Any Surface, from whence no Light is reflected, appears Black.

14. The Sine of Incidence and Refraction of the moſt refrangible or Violet Rays, in paſſing out of Glaſs into Air, is as 50 to 78; the Sine of Incidence and Refraction of the leaſt refrangible or Red Rays, is as 50 to 77; though hitherto the Sine of Incidence and Refraction out of Glaſs into Air has been inaccurately expreſſed in ſmall whole Numbers by the Proportion of 2 to 3, or 50 to 75.

15. The Proportion for the Refraction of Water and Air in the leaſt refrangible Rays, is 81 to 108; in the moſt refrangible Rays, 81 to 109.

This Theory of Colours is principally founded upon the *Phænomena* of thoſe Colours, which are exhibited by the Rays of the Sun tranſmitted through a Glaſs Priſm.

For the right underſtanding thoſe *Phænomena*, it is neceſſary firſt to know how the Sun's Rays would be refracted by a Priſm, according to the Laws of common Optics, which ſuppoſes all the Rays of Light to be equally refrangible.

For this Purpoſe I have calculated the following Table, in which it is ſuppoſed,

1. That the Refracting Angle of the Priſm is 60 Degrees.

2. That all the Rays are equally refrangible, and that they are refracted according to the Proportion of 3 to 2.

3. That the apparent Diameter of the Sun is half a Degree or 30 Minutes.

4. That the Axis of the Priſm is held perpendicular to the Sun's Rays, and parallel to the Horizon.

5. That the upper Surface of the Refracting Angle is at firſt held parallel to the Ray proceeding from the lower Limb of the Body of the Sun; and that the Priſm is gradually turn'd about its Axis, till it arrives ſucceſſively at the ſeveral Situations number'd in the firſt Column of the Table, 1, 2, 3, 4, *&c.*

The ſecond Column ſhews, at each Situation of the Priſm, the Angle of Incidence of two Rays, one proceeding from the upper, the other from the lower Limb of the Sun's Body.

The third Column ſhews the Angle of Refraction, in which thoſe two Rays emerge out of the lower Surface of the Refracting Angle of the Priſm.

The fourth Column ſhews the perpendicular Height of the *Spectrum*, the Diameter of the Hole at which the Rays enter being firſt ſubſtracted.

The fifth Column ſhews how much the *Spectrum* deſcends or aſcends, and where it is ſtationary.

Situations of the Priſm.	*Angles of Incidence.*		*Angles of Emergence*		*Height of the Spectrum.*		*Deſcent and Aſcent of the Spectrum.*	
	°	′	°	′	°	′	°	′
1	90	00	27	55	0	02		
	89	30	27	57				
2	80	00	29	11	0	08	8	44
	79	30	29	19			8	48
3	70	00	32	52	0	14	6	19
	69	30	33	06			6	13
4	60	00	38	52	0	21	4	00
	59	30	39	13			3	53
5	50	00	47	13	0	28	1	39
	49	30	47	41			1	32
6	49	00	48	11	0	29	0	02
	48	30	48	40			0	00
7	48	50	48	20	0	30	0	01
	48	20	48	50			0	00
8	48	00	49	11	0	31	0	01
	47	30	49	42			0	02
9	45	00	52	22	0	35	0	11
	44	30	52	57			0	15
10	40	00	58	27	0	43	1	05
	39	30	59	10			1	13
11	30	00	77	07	2	22	18	40
	29	30	79	29			20	19
12	28	25	83	41	6	19	04	59
	27	55	90	00			08	56

From the foregoing Table it is evident;

1. That from the firſt Situation of the Priſm to the ſixth, the *Spectrum* deſcends, becauſe the Alterations of the Angles of Incidence are greater than the Alterations of the Angles of Emergence.

2. That from the ſeventh Situation to the laſt, the *Spectrum* aſcends, becauſe the Angles of Emergence alter more than the Angles of Incidence.

3. That at the ſeventh Situation, the *Spectrum* is ſtationary.

4. That the Altitude of the deſcending *Spectrum* ſubtends an Angle leſs than the apparent Diameter of the Sun; but the Altitude of the aſcending *Spectrum* ſubtends an Angle greater than the apparent Diameter of the Sun.

5. That the Height of the *Spectrum*, in its Stationary Situation, ſubtends an Angle at the Priſm (of thirty Minutes) equal to the apparent Diameter of the Sun.

Note, That in the Stationary Situation of the *Spectrum*, if we conſider only that Ray which proceeds from the Center of the Sun's Diſque, the Angle of Refraction into the Priſm, and the Angle of Incidence in paſſing out of the Priſm, are ſeverally equal to half the refracting Angle of the Priſm; and the Angle of Incidence at the firſt Surface, is equal to the Angle of Emergence at the ſecond Surface.

Thus the Rays would be refracted according to the vulgar Laws of Optics; but by Experiment it is found in Fact,

1. That the Height of the Stationary *Spectrum* ſubtends an Angle at the Priſm of two Degrees twenty Minutes, which is one Degree and fifty Minutes more than the common Laws of Optics can account for.

2. That the Top of the *Spectrum* is Violet, the Bottom Red, and the Middle adorn'd with the five other primary Colours in their Order.

3. That the Angle of Incidence of Heterogeneous Light upon the ſecond Surface of the Priſm being thirty Degrees, (whoſe Sine is five hundred ſuch Parts, of which the *Radius* contains a thouſand) the Angle of Emergence of the moſt Refrangible is 51 Deg. 16 Min. of the mean Refrangible 50 Deg. 49 Min. and of the leaſt Refrangible 50 Deg. 21 Min. whoſe Sines are 778, 775, and 770.

Of the Permanent COLOURS *of* NATURAL BODIES.

1. IF the Thickneſs of a Plate of Air, incloſed between two Glaſs Priſms, be leſs than half the Interval of the Fits of Refraction, the upper Surface of the lower Priſm ſhall loſe its reflecting Power; for the Rays which are put into Fits of Refraction, as they enter the Plate of Air, will arrive at the lower Priſm before they are out of thoſe Fits, and ſo be tranſmitted.

2. The Intervals of Acceleration and Retardation, and conſequently the Intervals of the Fits of Reflection and Refraction, are leaſt in the moſt Refrangible Rays; juſt as the accuteſt Sounds produce the ſhorteſt Pulſes or Vibrations in the Air.

3. If the Thickneſs of the Plate of Air be equal to half the Interval of the Fits of the moſt Refrangible Rays, then the Violet Rays ſhall arrive at the lower Priſm in Fits of Reflection, and ſo be reflected; but all other Rays ſhall be tranſmitted.

4. If the Thickneſs of the Plate of Air be equal to half the Interval of the Fits of the mean Refrangible Rays, then the Violet, Indico, Blue, and Green Rays, ſhall be reflected, and by their Mixture exhibit a compound Blue; but the Yellow, Orange and Red Rays ſhall be tranſmitted and exhibit on the other Side a yellowiſh Red.

5. If the Thickneſs of the Plate of Air be equal to half the Interval of the Fits of the moſt Refrangible Rays, then all the ſeven Primary Colours ſhall be reflected and exhibit White.

6. If the Thickneſs of the Plate of Air be ſomewhat greater than half the Interval of the Fits, added to the whole Interval of Reflection of the moſt Refrangible Rays, then the Violet Rays ſhall begin to be in Fits of Refraction before they arrive at the lower Surface, and ſo be tranſmitted; and the other

Primary Colours continuing ſtill to be reflected, ſhall compound a Yellow, which, as the Thickneſs of the Plate is increaſed, and the other Colours are ſucceſſively tranſmitted, ſhall at laſt turn to Red.

7. In like manner, as the Thickneſs of the Air is gradually augmented, the Red ſhall diſappear; and a ſecond Order of Colours proceeding from the ſecond Fit of Reflection, ſhall be ſucceſſively reflected and tranſmitted.

8. Colours of the third and following Orders ſhall interfere with each other more and more at every Fit, becauſe of the Inequality of the Intervals of the Fits of different ſorts of Rays; and hereby a great Variety of compounded Colours ſhall be reflected, continually growing more dilute and imperfect, till at laſt all ſorts of Rays being pretty equally mixt and reflected at the ſame time, nothing ſhall be ſeen but an even Whiteneſs.

9. So alſo, if a thin Plate of Water or Glaſs be encompaſs'd with Air, the like Colours ſhall be reflected by the Attraction of the lower Surface of the Glaſs or Water, according to the Thickneſs of the Plate.

10. Colours of the ſame Kind and Order reflected from a Plate of Glaſs or Water, are more bright and vivid than thoſe reflected from a Plate of Air, becauſe the Attracting Force is ſtronger than the Repelling Force of the ſame Particles.

For if the Attracting and Repelling Forces were equal, any Ray refracted into a denſe Medium would be equally inclin'd to the Perpendicular with the Incident Ray; and if the Repelling Force were greater than the Attracting Force, the Ray would be refracted from the Perpendicular in entering into a denſe Medium, and towards the Perpendicular in paſſing out of it.

11. It is farther remarkable, that the Colours reflected from a Plate of Air, are conſiderably changed by changing the Obliquity of the Eye to the reflecting Plane; but the Colours reflected from a Plate of Glaſs or Water are very little alter'd by the Alteration of the Obliquity of the Eye. Hence it follows:

1. That all Bodies will appear tranſparent (by the firſt Article) whoſe Parts and Interſtices are too ſmall to cauſe Reflections in their common Surfaces.

2. That the tranſparent Parts of Bodies according to their ſeveral Sizes reflect ſome ſorts of Rays, and tranſmitt the reſt (as thin tranſparent Plates do) and that each Body appears to be of that Colour, whether Primary or Compound, which reſults from the reflected Rays: This is evident from the ninth Article.

3. That the Parts of Bodies on which their Colours depend, are denſer than the

Æthereal Medium which pervades their Pores; and that, *cæteris paribus*, the Colours are briskeſt where the Parts are denſeſt. This appears from the 10th and 11th Articles.

4. That the component Particles of thoſe Bodies are greateſt, whoſe Colours are moſt dilute and compounded, as may be ſeen from the 8th Article.

5. If the Particles and Pores of a Body are ſo ſmall as to reflect no Light, and yet ſo large as variouſly to refract the tranſmitted Light from one Particle to the other, till it be ſtifled and loſt before it can paſs thro' the Body; ſuch a Body ſhall be opaque and black, and (by reaſon of the Smalneſs of its Parts, and the Multitude of Refractions) ſuſceptible of the Influence of Warmth and Heat.

Of COLOURS *in the* CLOUDS, *and of the* RAINBOW.

WHEN Vapours are firſt raiſed by the Heat of the Sun, each ſingle Particle is endued with a repelling Force, which keeps all other Particles at a Diſtance; and therefore the Atmoſphere continues tranſparent, notwithſtanding the Vapours that are ſuſpended in it, becauſe each ſingle Particle is too ſmall to cauſe Reflections.

But when the Vapours of the Atmoſphere begin to be condenſed by Cold, and the ſingle Particles begin to unite with each other, and to form aqueous Globules of different Sizes; thoſe Globules, according to their ſeveral Sizes, ſhall reflect ſome Colours, and tranſmitt others, and thereby conſtitute Clouds of various Colours.

From theſe Principles we may alſo account for thoſe Crowns, or Concentrick Rings of Colours, with which the Sun and Moon are ſometimes encompaſs'd. For let us ſuppoſe the Sun to ſhine thro' a thin Cloud, compoſed of aqueous Globules all of the ſame Bigneſs; this being ſuppoſed, it is certain,

1. That thoſe Rays which paſs thro' the Globules, that are ſituated directly between the Sun and the Eye, paſs thro' the Centers of thoſe Globules without any Refraction.

2. That the Light which is refracted to the Eye, from thoſe Globules that are not ſituated between the Eye and the Sun, does not paſs thro' the Centers of the Globules.

3. That the more remote the Globules are from the direct Situation, the greater is the Diſtance of Light, in its Paſſage thro' them, from their Centers.

4. That the more remote the Paſſage of the Ray is from the Center of the Globule, the ſhorter is that Paſſage. Wherefore,

5. The Paſſage of Light thro' the Glo-

bules is ſhorter, as the Diſtance of the Globules from the direct Situation is greater. Hence it follows,

6. That if we ſuppoſe the Globules to be of ſuch a Bigneſs, that one of the leaſt refrangible Rays, in paſſing thro' the middle of the Globule, ſhall have (for Example) 250 Fits of Refraction; then at a certain Diſtance from the direct Situation, the ſame ſort of Rays, being refracted to the Eye, ſhall have only 249 ſuch Fits in their Paſſage thro' the Globule; and at a certain farther Diſtance, only 248 Fits; and at a certain farther Diſtance, only 247 Fits, *&c.* The like is to be underſtood of the intermediate and moſt refrangible Rays, only that the Diſtances are greater in the more refrangible Rays, becauſe in ſuch Rays the Interval of the Fits is greater.

7. At ſuch Diſtances therefore as are deſcribed in the laſt Article, the Sun ſhall appear to be encompaſſed with certain Rings of Colours, whoſe concave Part ſhall be Blue, and exterior Part Red; the firſt Crown or Order of Colours being made (as in the Example) by the 249th Fit, the ſecond Crown by the 248th Fit, the third Crown by the 247th Fit, *&c.*

8. It may eaſily be proved, that the Difference between the Diameter of any Globule, and the Length of the Paſſage of a

Ray through it, is equal to twice the Verſed Sine of the Angle of Refraction of the Ray into the Globule. Wherefore, if the Diameter of the Globule be ſmall, the greater muſt the Angle of Refraction be to make that double Verſed Sine equal to the Interval of the Fits; and conſequently ſo much greater will be the Diſtance of the innermoſt Crown from the Sun.

9. If the Globules are of different Sizes, the Rings of Rays equally refrangible ſhall be caſt at different Diſtances from the Sun, and hereby heterogeneous Rays ſhall be mix'd, and conſequently the Colours diluted, or render'd inviſible.

10. Every exterior Crown is broader than the interior, becauſe the heterogeneous Rays are ſeparated moſt by the obliqueſt Refractions; therefore the exterior Crowns ſpread more into one another, than the interior; and by ſpreading, interfere and mix their Colours, ſo that there is ſeldom more than two or three of them to be ſeen diſtinctly.

11. The more equal the Globules are to one another, the more Crowns of Colours will appear, and the more lively will the Colours be.

As Crowns are made by Colours *tranſmitted* thro' aqueous Globules, ſo the Rainbow is formed by Colours *reflected* from the falling Drops of Rain, and therefore never appears but when it rains in the Sunſhine, and is always to be ſeen by a Spectator in a due Poſition, when the Sun ſhines upon a rainy Cloud in a proper Situation.

No Colour can appear in any Drop of Water, unleſs the homogeneal Rays belonging to that Colour emerge out of the Drop, and fall upon the *Pupilla* parallel to each other: For if the Rays diverge, the Colour will be ſcattered and loſt before it enters the Eye.

It will be found by Calculation, that the moſt refrangible Rays emerge parallel out of a Drop of Water after one Reflection, at an Angle of 42 Deg. 2 Min. and the leaſt refrangible, at an Angle of 40 Deg. 17 Min. and the intermediate Rays, at ſome intermediate Angle. Thus the interior or primary Bow will be form'd, whoſe Breadth ſhall be 1 Deg. 45 Min. being Purple within, and Red without.

After two Reflections, the moſt refrangible Rays will emerge parallel at an Angle of 50 Deg. 51 Min. and the leaſt refrangible at an Angle of 54 Deg. 7 Min. Hence the Secundary or exterior Bow will be formed, whoſe Breadth will be 3 Deg. 16 Min. being Red within, and Purple without.

The Secundary Bow will be fainter than the Primary, becauſe ſome Rays are tranſmitted at every Reflection.

A COURSE OF Experimental Philoſophy.

CONTAINING,

I. *Demonſtrations of the Univerſal Laws of Motion and the Force of all ſimple and compound Machines.*

II. *The wonderful Effects of the Gravitation of Fluids.*

III. *The peculiar Properties of the Air, conſider'd as an* Elaſtick *Fluid.*

IV. *The Principles of Opticks, explaining the Nature of Viſion, of Reflecting and Refracting Glaſſes, and of Light and Colours, according to Sir* Iſaac Newton'*s Principles.*

NB. That the Courſe will contain not only all that is uſual, but likewiſe ſome conſiderable Experiments which are entirely new; and that the *Apparatus* itſelf is new and complete, and every thing contriv'd according to the lateſt Improvements. The whole being very diverting and uſeful, not only for thoſe who have learnt the *Mathematicks*, but for ſuch as are not at all acquainted with that Study, by which they may with Eaſe and Pleaſure come to the Knowledge of thoſe Things which cannot be attain'd any other way without great Labour and Application.

To be perform'd by Benj. Worſter, *A.M. and* Tho. Watts, *at the* Academy *or* Accomptant's Office *for qualifying young Gentlemen for Buſineſs, in* Little Tower-ſtreet.

MECHANICS.

COncerning the Univerſal Properties of Bodies.

Of Matter and *Vacuum.*

Experiments to prove a *Vacuum.*

The Univerſal Law of Gravitation explained.

The Law of Coheſion, or the Attraction of the ſmall Parts of Bodies, deduc'd from the Aſcent of Fluids in ſmall Tubes, and between Glaſs Plates, and Variety of other Experiments.

Experiments concerning the Repulſion of the Particles of Matter.

Of Electrical Attraction and Repulſion.

Experiments relating to Electrical Attraction.

The Electrical *Phoſphorus.*

Mercurial *Phoſphorus.*

Liquid *Phoſphorus.*

Solid *Phoſphorus.*

The Light of *Phoſphorus* augmented *in Vacuo.*

Concerning Motion in general.

Experiments to diſtinguiſh Motion from Velocity.

Experiments to explain the Nature of, and to find the Center of Gravity in all Bodies, and to diſtinguiſh it from the Center of Magnitude.

The Experiment of the Double Cone rolling upwards.

A heavy Body, which of itſelf would fall from a Table, hinder'd from falling, by adding a heavier Body to it.

Experiments about the Falling, Sliding, and Rolling of heavy Bodies.

Concerning the Center of Motion.

Concerning the Diſtance and Line of Direction of a Weight and Power.

Experiments to ſhew the whole Myſtery of the Feats done by *Sampſons*, or ſtrong Men.

Of Simple Machines.

Of Balances, which are either Scales or Steelyards.

Of the four Kinds of Levers.

Of Pullies, ſingle and combin'd.

Of the Wheele and Axle.

Of the Inclin'd Plane.

Abſolute and Relative Gravity.

Of the Wedge.

Of the Screw.

Compound Engines.

Sails of Ships, Wind-Mills, Water-Mills, *&c.* explain'd on theſe Principles.

Experiments to ſhew how Men or Horſes of unequal Strength may be made to carry or draw a Burthen in Proportion to their Strength.

Experiments to ſhew the Advantage of great and ſmall Wheels in Coaches, Carts, *&c.*

A general Method to determine the Quantities of Friction in all Engines.

Sir *Iſaac Newton*'s firſt Law of Motion demonſtrated.
That the Compoſition of Forces in ſeveral Directions, not contrary to each other, produces a new Direction in a Diagonal Line.
An Experiment to ſhew, that the Line of the Relative Aſcent and Deſcent of a projected Body, is the ſame; whether the Place from whence 'tis thrown be continually at Reſt, or in continual uniform Motion.
Objections againſt the Motion of the Earth, ſolv'd from this Principle.
The Centripetal and Centrifugal Forces of ſolid and fluid Bodies in Motion, explain'd and demonſtrated by Experiments.
Monſieur *Des Cartes*'s *Vortices* exploded.
Introduction to the Theory of Projectiles and Motion of the Heavenly Bodies.
How a Body will move, when its Projectile Force either yields to, overcomes, or exactly balances that of Gravity.
Sir *Iſaac Newton*'s ſecond Law of Motion demonſtrated.
An Experiment to ſhew that the Velocity of Falling Bodies is as the Times, and the Spaces gone thro' as the Squares of the Times of Falling.
The Force of Reſiſting Mediums conſidered.

A curious Experiment to explain the Foundation of the Art of Gunnery.

The Nature of Fortification explain'd from a large and curious Plan.

The Moon's Motion explain'd from the Doctrine of Projectiles.

The Motion of the Planets and Comets deduc'd from the ſame Principle.

The Solar Syſtem explain'd.

The Tides, and Phaſes of the Moon demonſtrated.

Experiments with the Load-ſtone.

Experiments concerning the Deſcent of Bodies on inclin'd Planes, being an Introduction to the *Theory of Pendulums.*

Experiments concerning Pendulums.

Center of Oſcillation explain'd.

A Cycloide deſcrib'd.

Cycloidal Cheeks for Pendulums.

The Motion of Pendulums alter'd by Heat and Cold.

That the Motion of Waves in the Sea anſwers to the Motion of a Pendulum.

Sir *Iſaac Newton*'s third *Law of Motion* demonſtrated.

Flying and Swimming accounted for.

Of the Nature and Cauſe of Elaſticity.

How to deſtroy the Elaſticity of ſome Metals.

Concerning the tremulous Motion of ſounding Bodies.

Experiments concerning the Laws of Communication of Motion in hard and elaſtic Bodies:

HYDRO-

HYDROSTATICS.

Concerning Fluids in general.

Experiments to prove that Fluids gravitate in the Fluids of the ſame kind.

That Fluids of different Kinds gravitate upon each other.

That Fluids preſs in all manner of Directions at the ſame time.

That the Quantity of that Preſſure in all Fluids is proportional to the perpendicular Height of the Fluid in all Parts of the containing Veſſel.

That any given Quantity of Water, tho' never ſo ſmall, may be made to preſs with a Force equal to any given Weight, tho' never ſo great.

To raiſe any given Weight by the Force of a Man's Lungs only, provided he blows thro' a Tube proportionably ſmall.

An Experiment of Lifting a Weight by a Chain of inflated Bladders, apply'd to Muſcular Motion.

Several other Experiments to explain the Hydroſtatical Paradox.

Experiments to ſhew how high, and why Water will riſe in Fountains and oblique Jets, and the beſt way of making ſpouting Pipes.

The Expence of Water ſpouting from equal Holes at at any given Diſtance from the

Surface computed, and ſhewn to be as the ſqure Root of thoſe Diſtances.

The Working of Syphons, ſucking, forcing, and lifting Pumps explain'd.

Experiments to ſhew that Bodies heavier than Water, when weigh'd in Water, loſe as much of their Weight as is equal to their Bulk in Water; and Bodies lighter than Water will ſo ſwim in it, that a Quantity of Water equal in Bulk to the Part immers'd, will be equal in Weight to the whole Body.

How upon theſe Principles Lead, or any Metal, may be made to ſwim in Water, and even rais'd up by it.

The Hydrometer.

The Hydroſtatical Balance to determine Specifick Gravities.

Glaſs Bubbles accounted for.

PNEUMATICS.

Experiments concerning the Nature of the Air in general.

That the Deſinty and Spring of the Air is as the Force that compreſſes it.

That the Preſſure of the Air decreaſes, according to its Diſtance from the Surface of the Earth.

Cupping Glaſs.

The Raſing and Falling of the Quick-Silver in the Weather Glaſs, explain'd and accounted for.

The different Sorts of Barometers.

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